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RELEASED ASHLAR—A PROBLEM IN ORNAMENTATION AND BUILDING CONSTRUCTION.

BY JOHN COTTER PELTON, MEMBER OF THE TECHNICAL SOCIETY OF THE PACIFIC COAST.

[Read before the Society, December 6, 1895.*]

THIS paper is prepared for the purpose of calling your attention not to any particular form of released ashlar construction, but to the subject of released ashlar construction in its broad application to modern structures.

I feel that it is a subject in touch with modern thought and in line with modern constructional progress. I think that in our progress toward the attainment in effect of a superior result, with a minimum of material, this form of construction may play some part.

I would not pull down the monumental memories of Greece and Rome, but I may ask of you, shall we ever again build a Parthenon or a Colosseum? Are not our investigations now in another and different field? Are they not influenced and governed by totally different exigencies and sentiments?

The architectural world of 1895 is not the world before Christ, nor is the world of to-day the world of to-morrow.

The day does not close, but sees, at some fellow-craftsman's hands, he improvement of a theory or the development of a better one.

* Manuscript received January 26, 1895.—*Secretary, Ass'n of Eng. Socs.*

I feel the sentiment in each subtle line of Grecian grace. The fragments of the Acropolis hill tell me of the men who brought their work to such perfection, and of the spirit which was THEIR influence, under which they lived and strove, but it was not the spirit which moves us of to-day.

I will confess to a profound awe in the study of the Parthenon or the Colosseum, as structures, but still I do not think, while engaged in that study, that any of us look forward to a commission to build a Parthenon or a Colosseum.

The pyramids are inspiring. That simple, blind piling up of stone upon stone was an accomplishment so herculean as to try the patience in the development of a tenable theory of construction, a work costing years of time, and the lives of thousands of human beings, and all for the construction of a receiving vault of limited size for the security of the remains or the treasures of a king. I cannot doubt that, for purposes of safe storage, the Greeks would choose, to-day, a modern safe deposit vault in preference to any of their temples.

But it is quite idle to make these comparisons. Let us ask each other, not, are we rebuilding pyramids, or Parthenons? but, are we building to-day even as our masters built? Are we building just as we were ourselves building, only a few years ago?

I hardly believe that any of us would confess that ours is the only craft not in that procession which moves slowly but as surely as the star of empire, with that profound sentiment, that unconquerable purpose, *the improvement of the condition of man.* But rather, may we not claim that through all ages, in architectural development will be found a certain and positive index of the condition of religions, of social and commercial life?

The impellant idea which I have had in mind in the perfection of a method of safe construction of a thin ashlar facing for a structural wall, is the minimum use of the more *costly and beautiful materials, stone and marble;* an idea originating possibly in the pyramids, and developing in the Latin countries early in the Christian era. I have hardly had time or opportunity to trace the earlier applications of the idea. We need, I think, go no further back than the pyramids of Cheops, where we may find the most positive and elaborate evidence in heavy ashlar of black granite on the exterior, and of more rare and beautiful colored granites and porphyry in the interior passages. Nor is it necessary to take up time in such an effort. We know that in the old world such ashlar is seen on every hand in many forms and degrees of thickness, frequently in the form of a mere veneering of inch marble.

St. Mark's, in Venice, from sill to spires, is of rare and beautiful marbles; and I am sure no question will be raised as to its permanency,

although the method of attachment was most simple, consisting only in wiring and cementing. I feel rather that a question would have been raised by this economical race of people as to the burying of costly stone in walls of unnecessary thickness.

All along the Grand Canal, in Venice, we find veneer construction from one to three inches in thickness, of marble and sandstone in palaces, dating back as far as the eighth century.

The Milan Cathedral may be mentioned as a notable example of marble veneering. In parts of the building, marble was used in heavy structural form, while later, from economical reasons, veneer construction on brick walls was substituted, and the building so completed, and this where marble is cheaper than in any other part of the world.

Passing now the economical use of costly or choice material, I will attempt the substantiation of my conviction of the superiority of the released ashlar form of construction. To make this clearer, let us separate the necessary elements of a wall—strength, rigidity, fire resistance and architectural character.

It seems clear that it may be demonstrated that a wall of proper construction, not connected structurally with the ashlar facing, is more perfect than a wall of composite character, say than a wall of bonded brick and stone masonry; at least where there is limitation of cost and of occupied space.

I trust I shall not be severely criticised when I claim that a wall of given dimensions, carried to a considerable height, is a more reliable and certain construction if of solid brickwork of good character, than if of bonded brickwork and stone. This difference is due to the wide difference between the crushing resistance of brick alone or of stone alone, on the one hand, and that of brick and stone bonded together on the other hand; and, also, by reason of unevenness in settlement due to the greater number of mortar joints in the brickwork than in the stonework. We may take the crushing resistance of brickwork at from 300 to 1,000 pounds per square inch, and that of the ordinary sandstones of this coast as varying, according to various authorities, from 1,500 to 10,000 pounds per square inch. I submit to you the difficulty of a satisfactory adjustment of this difference of strength in a wall which is built as a unit, and that, if the adjustment is not perfect, there can be no integrity in the wall.

I will not limit the comparison to the crushing resistance, but will risk criticism again in claiming, for a wall of uniform material, a greater degree of strength and permanence from any point of calculation.

The California Hotel and Theater Building is an illustration to which I will refer, with some diffidence, however, as I realize that there must be several views and differing versions to account for its erroneous

construction, but from no standpoint can the failure be considered as pardonable. There is error in calculation, error in choice of material, error in adjustment of incumbent weight, or error in workmanship by stone-cutter or by setter; and, although I do not suggest the shirking of either question when circumstances demand such a structure, I do, without hesitation, call your attention to the much more simple solution of each and every one of these features in the use of a wall of uniform material, *i. e.*, of brickwork with a released facing.

In the question of rigidity in emergency, such as vibration caused by heavy traffic, or the more severe strain imposed by the shock of an earthquake, I believe that investigation will again reveal the superiority of this construction.

The settlement of a wall of brick or of masonry is one of the vital considerations, if not the most vital, in such work. This natural settlement or contraction in average work has been estimated to be sometimes as much as $\frac{3}{4}$ of an inch in 10 feet of height, and every engineer, architect, superintendent of construction and builder knows the care, contingent upon such settlement, which must be exercised in the construction of the parts while the work is in progress. Even in buildings of moderate height this settlement may be of much moment; and, if it exists, it must be provided for somewhere or somehow. It can not be ignored. It must be traced in its effects, or failure in some part of the structure is certain. If this be applied to a brick wall of even and defined strength it is in itself serious; if applied to a wall of two different materials of differing strengths, it becomes worthy of most careful consideration. It must be admitted that the releasement of the facing absolutely solves this problem. The walls are carried to their full heights, almost the entire weight of the building is imposed, and the settlement or contraction has taken place, before the ashlar is set in place.

The question of the prevention of dampness in walls of buildings of brick, or of brick and masonry, has received your attention too often to require more than a brief mention. I will confess to a surprise in reading but recently of the use of hollow bricks in the walls of the Parthenon, built 430 years before Christ. The reflection, therefore, that allowing the absorption of a common brick to be one pint of water, the walls of the Mills Building, in this city, might, if exposed on all sides through their whole length, absorb no less than 420,000 gallons of water, or 1,680 tons, emboldens me to claim the overcoming of this fault of an ordinary wall as a third feature of advantage. Sandstone of the average density is hardly less absorbent than brick.

I will ask here whether, in the exact computation of the parts and functions of the parts of a modern structure, this additional weight should be ignored? I fear it often is. We are all familar with a

number of expedients, of forms of construction, devices in wall anchors, etc., designed to release the outer 4-inch facing of a brick wall, and for the purpose only of protecting the inner or structural wall from the accumulation or absorption of dampness; and I believe that within a few years this form of construction has been recognized as the most successful, in fact the only form certain of the accomplishment of the purpose.

I cannot but feel convinced that, by the provision of an air space, much will be accomplished in the equalization of the temperature, not only in the avoidance of the dangerous dampness, but in protection against the effects of changes of temperature in the outside air. I submit that if this can be admitted, it is a consideration of importance in climates demanding the heating of buildings at great expense.

As to the question of fire resisting qualities, I think I can again demonstrate superiority due to the space filled with air between the structural wall and the ashlar facing, and suggest that, until the outer facing has been destroyed and fallen off, the wall itself remains cool and unaffected by the heat. With reference to the facing as a protection against fire, certainly much depends upon the selection of a material of superior fire-resisting quality.

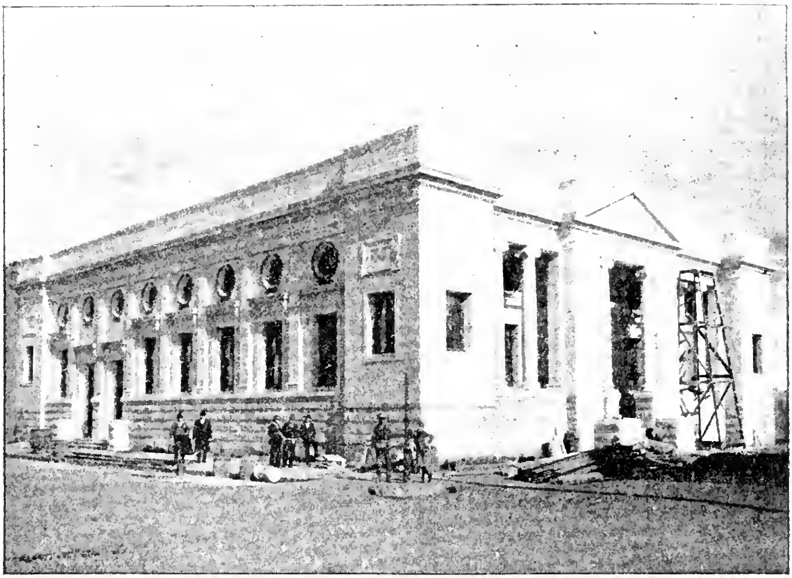
I may suggest, in the event of a partial destruction by fire of a building so constructed, the possibility of making repairs without the total demolition of the wall, and here I will pass the reviews of the practical structural functions and will conclude with a few words on the resultant features of rapidity of construction and economy of property area.

No general estimates can be made of either of these features, or of the amount of time which may be saved, or of the saving of space occupied by walls. Such estimates require special comparison. That such construction may be rapidly prosecuted is evident, the walls being carried to their full height without interruption and without delay in the preparation of the material for the façade, in which, whether of brick and terra cotta, or of brick and stone, may usually be found the cause of delay, consequent upon its more elaborate character and the slower process of ordinary construction. The building being under roof and inclosed, the prosecution of the work of the interior is made entirely independent and may be begun at a much earlier period.

Time is usually of sufficient importance to be considered in any business undertaking. In a building enterprise the first question of importance, after that of cost, is the time which must be given to the work of construction, and many plans and methods are taken advantage of to facilitate progress and to hasten the occupation of the building and the opening of the rent roll.

The loss from the area of land, in space occupied by the walls, I do not believe is always appreciated. I am quite sure it would startle the owners of some buildings of even recent date. The Mills Building, in this city, loses, in its walls, 12 per cent. of the lot area. The Crocker Building loses 18 per cent. and the Chronicle loses 21 per cent. This represents a loss in income, and any saving in such loss means just so much increase in the income.

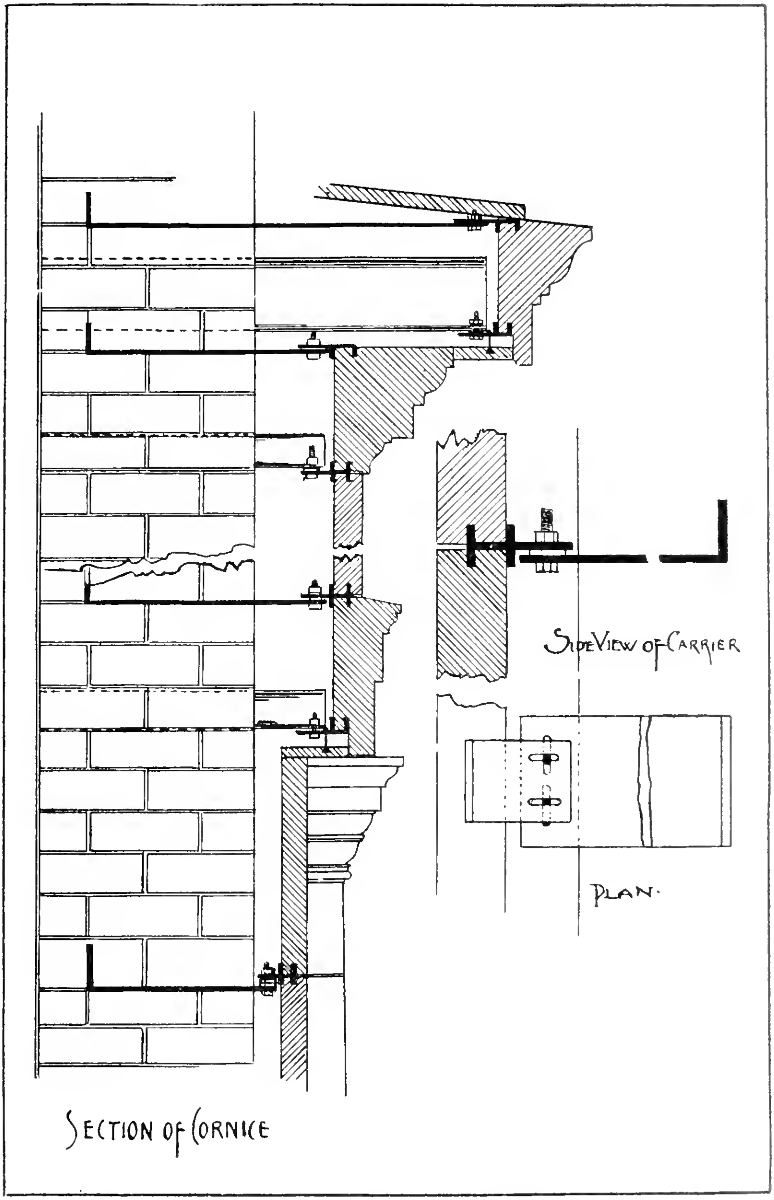
The first building to which I applied a marble facing was built on California Street, near Devisadero Street, in this city, for Mr. John I. Sabin, some four years ago. This was a wooden building, and was



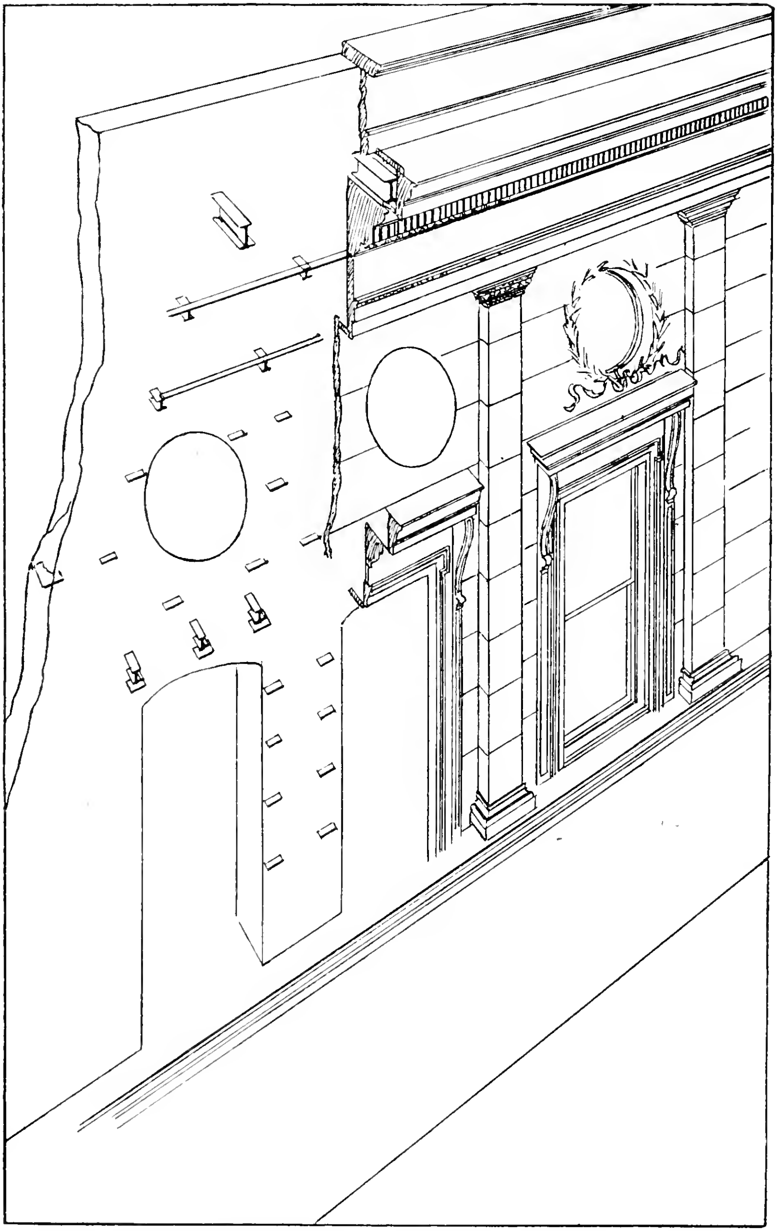
STOCKTON LIBRARY BUILDING, SAN FRANCISCO.

faced to a height of about 10 feet, this height representing about the extent of my confidence in the safety of 2-inch marble. I could figure to do much better, but did not feel quite prepared to undertake a greater height.

The next occasion presented itself in the Telephone Building at Los Angeles. The character of the design called for uniformity of material. The height was about 30 feet, and there was, with the limit of my first experience (10 feet) in mind, developed the idea of dividing this height of 30 feet into three sections, and supporting the weight of each section independently, *i. e.*, transmitting it to the wall. This may be called the first step in this method of ashlar construction, *i. e.*, the interruption of



STOCKTON LIBRARY BUILDING, SAN FRANCISCO.—DETAILS.



STOCKTON LIBRARY BUILDING, SAN FRANCISCO.—SECTION OF FRONT.

the accumulation of the weight. The walls of this building were built, the carriers were set, and the setting of the marble had progressed to the height of the first interruption or carrier, when it was discovered that the variation of these carriers from the proper measurements was so great, and the alignment so irregular, as almost to cause an abandonment of the proposed façade, and this was with difficulty overcome. Here came in the attachment of a second and separable bracket or shelf, with means of adjustment to this irregularity of setting and alignment.

The construction of the marble Library Building at Stockton, California, with a frontage of 210 feet, was then undertaken and carried to a successful issue.

I trust I am not over-confident in saying that this piece of work has demonstrated the feasibility of the constructional principles here advocated, and that an examination of its details will substantiate the claims which I have made for the released system of ashlar construction.

Let us now look for objections; if this is *not* a proper form of construction, there must be clear and tenable reasons, readily stated.

Let us first look for these objections from an artistic or æsthetic standpoint. I have sought earnestly, and am unable to find, an æsthetic law of thickness. I find nothing to justify the term "veneering."

I have never heard an artistic comment upon the thickness or the amount of paint upon an artist's canvass. It is the expression, the character or the sentiment, which appeals to us. In fact, I cannot find in the world of art, or in the æsthetic history of architecture, anything about the thickness of such facings. To be more practical, I have never heard the term veneering applied, except by the ignorant, to the architectural facing of 4 inches of pressed brick in the usual form.

Now, from a constructional standpoint, I am unable to figure out a practical defect which cannot be provided for. I will state two which have been brought to my attention, which have been certainly worthy of the most careful study and investigation, and to which I am prepared to make answer; but upon these points, I feel that much more can be said, and I trust that if this subject seems to you to be of interest, or if the perfection of such a system of construction is of value, some discussion of these questions may ensue.

These questions are: the possibility of leakage through the joints, and the grinding tendency caused by vibration in a tall structure.

The question of leakage, I think, may be answered by proper attention to the workmanship. I have not heard this question raised against the use of a facing of pressed brick, having a multiplicity of joints. Why, then, should it be raised against a construction by which this very possibility is reduced five-fold. Still, it has been suggested by Mr. G.

W. Percy, in his report to the Harbor Commission, that, should such danger arise through accident or careless workmanship, means may be provided, in the space behind the facing, to care for such seepage.

In the consideration of the question of the tendency to grinding, it may be observed that it must be a very tall structure in which this action would take place; but believing that here also the result will be found satisfactory, I am prepared to allow to it all the importance which the most careful and technical practitioner may think necessary. In fact, does not the consideration of this very question result in favor of the interruption of the facing frequently in the height of such a building and thus lead to another finding in favor of the method? As to the thickness of the facing and the frequency of the interruption, I may say that one balances the other; for, as the facing increases in thickness, the interruptions should be made at more frequent intervals.

As to the forms of the carriers or anchors, this, of course, depends upon their position, or upon the duty which they must perform, and varies constantly according to the architectural character of the façade, etc.

Something might be said of the adaptability of this method of construction to various designs, but it seems unnecessary; for, although familiarity with this form of construction might lead to more simple and readily applied design or style, it is but a matter of more or less study to make its application satisfactory in any example.

I may state that in the construction of the Stockton Library Building, where the Grecian Ionic style was used, no detail was sacrificed in the application of the construction. The style was fully carried out in all its parts and in every detail.

The respective projections are provided for, simply by greater strength in the parts.

In the treatment of exposed corners, reference may be again made to the Library Building and to the Telephone Company's building, in no part of which structures is the thickness of the material evident, and how much more readily this may be effected in the freer Romanesque or Renaissance details, need only be suggested.

I feel that in the application of this form of construction to a modern building with steel framing, there is possible a most perfect achievement, attaining a degree of perfection beyond any form now in use, *i. e.*, the strength of the structure may be secured in the steel frame, a minimum of material being used for the protection of this frame from fire, and a minimum of material being required for the facing.

DISCUSSION.

President Dickie.—While we have had very little architectural matter to discuss in this Society, the subject is exceedingly interesting, not only from an architectural, but also from an engineering point of view. I trust that it will be fully discussed, and that no point concerning it will be left in the dark.

I can conceive of many advantages that this construction presents, especially in our State, where we have so many kinds of building stone, and such a variety of marble to be utilized.

One point which was not brought out in the paper, and which I thought of while it was being read, is, that the facing work might be prepared in a factory, jointed and put together, polished and finished, and taken to the building complete, and ready for erection, as is now done with woodwork.

Mr. H. T. Bestor.—It will be interesting if Mr. Pelton will take the blocks of marble and the iron anchors that he has exhibited here, and show us how they are put together, and also explain his facilities for alignment of the blocks.

Mr. Pelton.—What we know we have learned through the correction of errors. For instance: I made a mistake in trying to secure a proper and correct placement of fixed carriers in the Telephone Building at Los Angeles. When we got up to the point of second interruption, the anchors were not there; they were about a quarter of an inch out of their proper position, and I believe some of them were three-quarters of an inch out. At first, that defect seemed almost insuperable. It gave rise to the use of an adjustable or secondary shelf. The first shelf is built into the wall while in course of construction, in the joint next below the level required to meet the course of stone. Then, when the ashlar is to be set, a secondary bracket or shelf-rest is put on, and adjusted by means of washers to the exact position required (the bolt is then set). The lower slab is let in before the bracket is fixed. Then comes the next course, and the thickness of the anchor represents the thickness of the joint. The joint is then filled in with cement.

With a fixed carrier, constant and careful attention had to be given to the plumbing of the face. In any masonry construction, much time is consumed in the exact setting. I found that many pieces of stone had to come back to the ground and be trimmed over again. I think Mr. Dickie has made an excellent suggestion. It would certainly secure a much more perfect and much more rapid and effective method of construction to have everything come from the shop or mill quite ready for setting.

The anchorage of the blocks is made in a slot cut in the edge of the block, to receive the forward lug of the anchor.

The form of anchor referred to this evening is that required for a thin wall-covering; that is to say, for a thickness of two inches. When we come to projections we get into a field requiring a little calculation. We have to consider the weight to be carried, the form of the anchor must be varied, and they must be made heavier.

The width of the air space is a matter of choice. I think a space of two inches as good as a foot.

As to the effect of contraction and expansion due to great variations in temperature, as in the case of a fire across the street, I may say that I have thus far confined myself to marble facing in connection with this construction, and marble will stand more heat than any other stone. In case of a fire it would have to burn to lime before it would fall. I think the air space would keep the walls cool, and that we need not expect much difficulty from this source. As stated in my paper, in case of destruction by fire, or possibly by some other cause, of a section of this construction on a building, the means of the reapplication of it is still there, as the wall itself and the anchors might not be injured.

Q. Would that wall have as much stiffness against the wind as a solid wall?

A. The element of strength is represented by the wall; the ashlar facing is not a part of the construction.

Upon the question of vibration I should like to hear all that can be said. I believe it is the most important question that has been brought out. The question of leakage, as I said before, I think may be overcome by careful workmanship. Mr. Reid has suggested that it is possible, in a very tall structure, to start such a vibration as to create a grinding tendency. That may be so, but if there should be a grinding tendency, these very interruptions will stop it. If the grinding is established, I hope also that I may be sustained in the proposition that it has been overcome.

As to the effect from the heat of the sun, I do not think the expansion, followed by contraction, would cause any trouble in brick or stone walls.

Mr. Dickie.—We have large amounts of metal in all kinds of walls nowadays, and there does not appear to be any difficulty or danger from expansion, whether it be equal or unequal.

Q. Are not anchors made very light for holding walls together and holding pieces together?

Mr. Dickie.—We have walls with steel girders built in with them, the wall being simply a panel, and the expansion does not seem to open any joints in connection with them.

In listening to this paper it has occurred to me that the fastenings adopted are rather crude. Suppose we had a brick wall, and were intending to put on it a face of another kind of material, say of marble.

I would put my anchors into vertical lines at such intervals as was most convenient, allowing some of them to project farther than others, according to the shape of the outside piece; and on these anchors I would place a strip of metal, say a 2½-inch bar, which would take the form of the projections intended. This would be put in the wall, and the face would be put on afterwards, plumbed and fastened. And then, for seams, I would simply have a little channel-bar running along horizontally and fastened to a shelf, and this would break the joint so that water could not get in. By that means the whole structure can be completed before the bars are put on.

If it is necessary to drill holes in the 2½ by ½-inch strips, they can be drilled.

Mr. Bestor.—In St. Louis, in 1859, we put anchors into the brickwork, and the brickwork would settle, while the stonework would not settle to the same extent, and finally the stone slabs would be thrown out of line. There will always be a settling of the brickwork for some time after laying, and that will crowd the channel iron chains very closely on the stone, thus the stone may be so closely pressed as to break the inner lip. The use of the iron anchors as proposed by Mr. Pelton appears to have many points in its favor.

While the Bank of California was building, the joints of the stone were raked out to a depth of ¾ inch, and the pointing was done soon after the brickwork was finished. The first earthquake thereafter, the stone in many places broke away from the joints. If the stone had been put on so as to have had some support from anchors, as proposed, it would have helped very much to protect the joints.

Mr. Dickie.—As I said before, this method seems to be very crude. A hole has to be cut in the stone to take the lug; but in the method I suggest, the stone would be put through a machine and cut out just as pieces of flooring are; the blocks would rest on the iron, and when these two faces came together on the outside, it would have a strengthening effect.

Mr. Pelton.—One of the defects I brought out was these fixed points. I am trying to avoid them.

Mr. Dickie.—In the case I present they would not require to be fixed.

Mr. Pelton.—Something has to be fixed.

Mr. Frank Shea.—Instead of the idea suggested by the President this seems to me the proper way of construction, and that accurate workmanship could be obtained by bringing anchors from the steel frame to carry this outer covering. This would do away with the many troubles that arise in other methods of adjusting the blocks afterwards. I think it is poor policy, in the light of modern thought, to build heavy

walls of masonry, and that it is better to have a steel framework and a rigid curtain wall, and then we have an accurate line for the placing of the different parts.

Mr. Dickie.—I have no doubt that this method of construction, should it prevail, will lead to the abandonment of both stone or brick in outside walls altogether. I have no doubt about that. I am rather astonished that architects talk about stone and brick for heavy walls. Why not have walls that are bolted and riveted and lapped, the same as we build up a ship or boiler? Then the ornamentation can be put on outside of that, as you wish. Our architects are sleeping; they do not think about those things. Some day some of us boiler-makers and ship-builders will build the houses, and we will get the architects to come and put on the adornments after the box is put up.

Mr. Frank Shea.—The architects are not sleeping in that regard. The Eastern structures are in line with the suggestions that the President has made, and they are not at all new to the world. Our greatest structures in the East are made of a steel frame, and the covering has almost resolved itself down to a covering of boiler plates. The idea is to do away with as much wall surface as possible. There are buildings, with walls 4 to 8 inches in thickness, that run up to 15 and 20 stories in height.

I think this is a happy time for the discussion of this subject, because the architects now look to the engineers with the greatest of interest, and as co-partners and co-laborers in the work of construction. The idea of heavy solid walls is being abandoned, and your idea of building, Mr. President, is being adopted in its truest sense throughout the country. We have many buildings of steel frame, with a covering only of cast iron of from ½ to ¾ inch thickness.

Mr. Dickie.—This method of construction is not very different from our old method of our cast-iron ornamented fronts such as are seen in some buildings in this city. The outer part is carried up in very much the same way as this method, only one is a ½ inch iron casting, while the other is 2 inch marble.

Mr. Bestor.—The facing of the Safe Deposit Building in this city is of stone and the pilasters are stone bonded into the brickwork, but the old cornices (which have lately been taken down) were made of galvanized iron. A portion of the Nevada Block is of cast iron. The columns and window frames were of cast iron. The London and San Francisco Bank has a cast-iron sheathing. The basement and first story is cast iron.

Mr. Pelton.—The ideas brought out this evening all tend to the minimum use of material. This, with a maximum degree of strength, perfect protection against fire, and a façade still expressive of architectural grace and dignity, I feel, makes up a worthy combination.

OBSERVATIONS OF ENGLISH RAILWAY PRACTICE, WITH SOME ACCOUNT OF THE FIFTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS.

By George B. Leighton, Member of the Engineers' Club of St. Louis.

[Read before the Club, January 8, 1896.*]

It may be said of the railway as well as of the common law, that they are the creation—the child—of the Anglo-Saxon mind, as of political and religious freedom. The important steps in the development of these great economic and social forces and conditions, enabling men to live together in the highest development of civilization, have been brought forth by the English mind. The locomotive, the steel rail and the power brake, are the inventions of Englishmen or Americans.

An American, however, in order to understand the real workings of railways in England, must familiarize himself thoroughly with the conditions that exist there, largely the results of race and of national characteristics. The conditions affecting the traffic working of English railways are materially different from those in the United States. Although the mileage in the United Kingdom is about one tenth that in the United States, the number of tons handled per annum is nearly one-half those handled here. In Great Britain, small shipments, to be carried to one of many stations, are presented to railways. These, owing to the proportionate relation between the actual haul and terminal expenses, go by themselves. In this country, we should place many of them in the same car, and reload into a local car in transit. In England, this transfer would necessitate great delays. Again, English rates are based on the ton as a unit, where ours are based on the carload. The average carload in England is not over three tons, but trains are moved with great promptness. Even some freight trains are scheduled at fifty miles an hour.†

Again, in passenger traffic, with us it is exceptional that a full train can be expected from one terminal to another without intermediate stops. Most of our trains are obliged to do somewhat of a local business. In England the numerous cities, comparatively but a few miles apart, furnish a traffic equal to that between New York, Philadelphia and Washington. Scotch and Irish railways more closely resemble those in

* Manuscript received January 27, 1896.—*Secretary, Ass'n of Eng. Socs.*

† Ackworth—The Railways of England, p. 101.

our country, many of them having but a single track. There are in the United Kingdom some 20,000 miles of railway, of which half have additional one or more tracks.

I shall endeavor to describe some of the salient points, which to my mind are of interest to a close observer of English railway practice, but shall not attempt to describe well-known characteristics. I will devote some words to the International Railway Congress, which held its fifth session in London last June, closing with a few remarks on the delightful social gatherings which took place on that occasion.

In observing a railway and its workings, it is natural to begin with the line and its construction.

The topography of England is of a rolling character—in places almost mountainous. The early railway builders so firmly believed that an engine and a car could not operate successfully on short curves or on heavy grades that the early lines were constructed on long planes and with curves of large radius adapted to the rolling stock, all of which had rigid wheel base. This involved the crossing of wide valleys by means of high bridges and the construction of tunnels. Hence the (capital) cost was necessarily great. Unfortunately the clearance allowed by the early works was small in width and height. These are general characteristics of the English trunk lines. But there are heavy grades and sharp curves in England, and more especially in Scotland and Ireland. Even on the great trunk lines, upon which the remarkable runs of the past summer have been made, there is at one place, known as Beattock Bank, a distance of ten miles with a continuous grade of one and a half per cent. The summit of this line is ten hundred feet above the sea. In the early construction of lines in England, as with us, sharp grades were worked by stationary engines. There is one grade on the Birmingham and Gloucester, now a portion of the Midland Railway, which, as early as 1838, was worked by American locomotives, on account of their ability to do hill work.* On the Lancashire and Yorkshire, grades of upwards of three per cent. are worked in freight service, but not on the main line.

A prominent characteristic of the English railways is, that they have been built to endure. The substructure of English lines is solid. The cuttings are well sloped and well drained. Where possible, masonry viaducts are used. The bridges have enormous weight and strength. Single track construction has been carried out on this same general scale. Important stations are of brick or stone, well lit by glass roofs.

From the early location of many of these lines, it is easy to infer that the engineers were more or less limited in their choice of location,

* Williams—History of the Midland Railway, p. 76.

that is, but little lateral variation in the right of way was permissible. At that time, the owners of estates and boroughs did not want the unsightly locomotive to cross them. The consequence of these conditions was that enormous prices were paid for rights of way and leases. To this day the North Eastern Railway is paying nearly a quarter of a million dollars annually for leases of rights of way; they would like to change their line and acquire the ownership, saing this great expense. However, the English landlord, at first desiring to be compensated for the injury to his property by the trespass of the locomotive, is now unwilling to lose this source of revenue, having decided that the locomotive is not so bad after all. A Bill to enable this company to so change its right of way has been defeated by the landed interests at several sessions of Parliament.

So far the American is pleased with the construction of the English lines, and wishes that he might have as good here. But, pausing to notice the track, he does not feel anything like the same degree of envy. The universal track construction in England is that of the double-headed rail of 75 to 90 pounds per yard; tie chair with ten ties (Baltic fir, generally creosoted) to a 30-foot rail, 5 inches in thickness and 10 inches on its face. In Ireland there is a considerable amount of "T"-rail. Steel ties, although somewhat extensively tried on the London & Northwestern, have so far not met with success, warranting adoption.

Average English rails appear to be better rails than the average American, but opportunity is not offered to discuss this fact. The joints on English railways are loose, often low, the click being very noticeable, and are not as good as on most trunk lines in America. The joints are necessarily suspended and have the common fish-plate. Most of the lines in England key their rails with an oak wedge on the outside of the rail, but on the Midland the wedge is on the inside. This lack of uniformity is an instance of the individuality in details of practice, that I shall endeavor to emphasize in these remarks. The Clearing House regulations necessitate uniformity in traffic affairs, and the Board of Trade in other directions, but aside from these there are marked individualities. The London & Northwestern Railway is using in the main line 60-foot rail, but it is alone in this practice.

Our next thought naturally leads us to some consideration of rolling stock. This is tending towards standard types, especially in engines. While the single driver engine is in use on the Great Northern, with apparent satisfaction, the standard English passenger engine of to day is one 18 x 24 inches inside connected, having four coupled drivers, and a bogie or common truck leading, and a deep copper fire-box. On the Northwestern, and following it in many respects, the Lancashire & Yorkshire, a truck with a radial axle-box is substituted for the common

four-wheel bogie truck. The weight of the average English express engine alone is about 45 tons, of which 30 tons are on the drivers. This gives an approximate weight on each driver of about 7½ tons, which is not so much less than on many of our passenger engines. When there is taken into account with this the immense traffic, it will be seen that the English track has a considerable work to sustain.*

Freight engines are six-coupled without trucks, their weights being often upwards of 50 tons. There is a type of engine in use in England designed for short runs under fifty miles having side tanks. This engine runs equally well in either direction. Boilers are straight.

On some English lines the Ramsbottom track-tank is in use. The advantage of this in passenger service is already appreciated by American lines, but the point seems to escape notice that in handling freight on a busy line there is much to be gained by this device. Freight trains run from Crewe to London, a distance of upwards of one hundred and fifty miles, without stopping for water. The use of the track-tank allows the use of smaller and lighter tenders. The standard tender of the London & Northwestern goods engine is only 1,800 gallons, but on this point again English practice is not uniform. The Great Northern Railway, being part of the East Coast line to Scotland (one of the lines making the fast runs), does not use the trank tank, and is thereby forced to carry a tender of large proportions and great weight.† There is a lack of uniformity in locomotive working as to the position of the runner. The London & Northwestern, and again on the Lancashire & Yorkshire, whose Locomotive Superintendent, Mr. Aspinall, is a pupil of Mr. Webb, place the runner on the left side of the engine. With the exception of these companies, and smaller companies allied to them, the universal practice is for the runner to be placed on the right side. Trains run on the left track. An English runner is a man markedly different in his thoughts and attention from an American runner. On American lines a runner is constantly peering ahead to ascertain and assure himself of the condition of the line, but owing to the universal "absolute" block system in use in England, an engine runner gives but little thought comparatively to this part of his work. When he sees the signal "clear" he assumes the line is clear and gives more attention to the working of his engine than he does to the line while on the block. I must not be misunderstood that he does not look ahead at all, but his chief attention is devoted to the fire and the steam gauge. The working of an English engine on a run may be likened to a popular piece of music in vogue some years ago, which began very faintly, increasing in

* Aspinall—Question VI. International Railway Congress. Express Locomotives.

† The same, p. 35.

intensity and force and then died away. The English engine on a long run, as a rule, has sufficient steam to start its train away, but gradually works up the fire and steam, while towards the end of the run the fire is allowed to die down.* The throttle is worked fully opened.

Returning to rolling stock, the English carriage stock, or coaches, is tending towards several standards for different usage. The second class is disappearing, leaving but a first and third. In through service the vestibule train, with through communication is in general use. But the comfort of these and capacity of freight cars is materially affected by the restriction to 8 feet 6 inches wide and to 13 feet in height.

On the London and Northwestern, the dining cars resemble American construction in much detail. They have six-wheel trucks and are 70 feet all over, weighing upwards of 50 tons.

Can this be said to be light stock? For short run service, the side entrance carriage has many points in its favor, and will no doubt remain the English practice to the end of time. Coaches with six wheels rigid, do not average over 30 feet in length. The bogie truck, however, with four wheels, is coming into use on most lines, and consequently a longer body. Here, again, there is conspicuous lack of uniformity, in that on one of the great systems, the Great Eastern, there is not a bogie truck on the entire system either under an engine or car. The light construction of passenger cars has been disastrous in many accidents. Cleanliness and neatness are especially noticeable in the care of cars and engines.

In freight equipment the cars or wagons are short, and carry as a maximum load, 10 tons per axle, including the weight of the car. The use of the short car has advantages in conditions which pertain in English working—a long car would have but the same load. The system of turntables for shunting in use at freight stations precludes the use of long-bodied freight cars.

In station service the English practice is different from American, and more efficient for English usage. It is questionable if, in some respects, it would not be preferable with us. At passenger stations platforms are on a level with car sill, which, with the side door, enables one to step quickly and safely from the car to the platform. It is noticeable that in two instances where we have in this country the densest traffic, this practice has been resorted to—on the New York and Chicago elevated lines, and on the Illinois Central in the World's Fair traffic and suburban travel. It is a mistake to imagine that trains cannot be unloaded quickly from side doors. We could not profit by the adoption of the side door generally, but is not the tendency to a low platform, now prevalent in this country, a mistaken one? To expect a short per-

* British Locomotives. Coope, Chapter XIX.

son to climb up on a train, or to climb from it, is wrong, and sooner or later it will arouse popular indignation, as it has done in Ohio, where there is a law making the maximum distance between the car-step and the platform 15 inches. Owing to our car-steps, platforms cannot be on a level with the sill, but they can to advantage rise 15 to 18 inches above the rail. The theory would now seem to be that baggage-trucks must be able to run around a station like balls on a billiard table, and that personal comfort must be subservient to this. Passengers can be better relied upon to keep out of the way of trains by offering them a safe and convenient platform, and not tempting them to trespass on the track.

As one alights from an English train in a terminal station, he sees the cabs are alongside the train. He quickly gets his baggage, which is in compartments through the train, and is away in less time with his baggage, than he can be in this country. The assistance of station-porters, ready to assist with one's hand luggage, is most desirable. In connection with the stations, the English railways have established, as a part of their systems, large terminal hotels, which are efficiently managed and highly appreciated by the public. They have also established, in the more picturesque parts of the country, commodious hotels in the nature of resorts.

In freight station service, there is a conspicuous difference between American and English practice. Generally, English local rates are based on the idea of store-door receipt and delivery, in which case the company conveys the goods to the station by its wagon, and delivers them by wagon to the consignee. This enables the company to have full control of the wagons at the station-yard, and to allow a wagon to remain loaded for some hours, the horses being detached and used on another. From this practice has grown that of collecting the goods during the day, and not attempting to load the cars or trucks until afternoon, then the loading is proceeded with, with great rapidity, the wagons being backed up against the platform, and trains are dispatched promptly and frequently. After midnight, incoming trains arrive in the same station, goods are loaded into the wagons, now empty, which brought in the goods in the early evening, and at daylight horses are brought into requisition and the goods promptly delivered. Several London freight stations have two stories, the underground part being devoted to the loading of cars, and the other to the marshalling of trains, a hydraulic car elevator being used.*

At the Broad Street Station of the London & Northwestern Road, one elevator performed the entire service when I visited it, delivering

* Turner—Question X. International Railway Congress.

a car about once a minute. In the lower story there is a central line, with hydraulic turntables, to which the cars are pulled from short bays by hydraulic capstans, and in this way passed along one after the other in station order, so that as the train appears above the ground it is ready to be dispatched. But, in the Midland Station, in London, the use of the turntables has been abondoned, and the short bay lines feed directly into a load, as we do in this country. This track terminates in an elevator, thence to the line above, as in Broad Street.*

No description of English traffic would be complete without some reference to the gravity yard of the London and Northwestern at Edge Hill near Liverpool.† The yard is designed to assemble traffic from the several Liverpool stations, to marshal it and dispatch it way. It is also used to break up trains arriving at Liverpool. But the outward traffic is more than double the inward, consequently, more than half the inward trains are empties. The outward traffic in 1894 was about a million and a quarter tons. Trains of outward traffic are brought from the various docks to the upper end of the yard, where the engine is cut off. The trains are shunted into line and station order by dropping a grade of about one per cent. The arrangement consists of reception lines, leading into a throat, where the grand division is made of traffic going north and south, these in turn feeding into twenty-four sorting sidings, where the trains are arranged in train order, and they drop from there into another group which arranges them in station order. From here, they are dropped again into the main outgoing line five minutes before train time.

The English freight trucks or cars have only a hand brake which consists of a long lever at the side of the car, pressing down two wooden blocks on one pair of wheels. These the operators in the yard use in checking the progress of the car, but in case of emergency, the normal condition of the lines in the yard is such that, if a runaway should occur, it is gripped by a hook which drags a heavy chain coiled in a receptacle. There are six of such devices in the yard. The working of switches within the yard is manual. Trucks are inspected on arrival, but the men are provided with a brake stick, with which they steady a car having a defective brake.

The average number of trains leaving this yard in twenty-four hours is about sixty, and to illustrate the diversity of traffic in England, we are informed that the average departure for London in this yard does not exceed two trains a day and often but one. Then again it is

* Ackworth—Railways of England, p. 103, etc.

† Statements from a Descriptive Circular Specially Prepared for Visit of the International Railway Congress.

to be remembered that there are many stations in London. This again would prohibit full utilization of the large car. The average English load is about three to four tons, where ours is about ten. The average English train load is about one hundred tons, where on our trunk lines it is upwards of two hundred and fifty. About three thousand trucks pass through this daily, the number of men being employed being slightly less than a hundred. English mineral traffic is carried in private cars; the building and maintenance of these is the subject of strict regulations, but even so, they often cause annoyance, not to say accidents.

We cannot dismiss the subject of operation without a word in regard to the fast runs which have been made on two leading English lines during the past summer,—the East Coast line and the West Coast line from London to Aberdeen, the distance by the East Coast line being 523 miles, by the West Coast, 539. Both lines are undulating, having considerable grades of over one per cent. There is an immense tourist travel to Scotland in August, and these trains were run largely as advertisements, the more barbarous practice of rate-cutting having passed out of existence. A former race was carried on in 1888. "The conditions having somewhat changed since then, the two rival lines decided to try their metal again. The chairmen of all the English lines deprecated racing at their annual meetings, which took place in July, but later said, when reminded of this fact, that the other fellow began it. On August 19th, without giving public notice, the East Coast line shortened its time to Aberdeen, but was surprised to find on the first run that the West Coast train had arrived there before it. Though public notice had not been given of the proposed acceleration, it was necessary to notify the Caledonian Company of the time that the East Coast train would pass Kinnabar signal box, sixteen miles from Aberdeen, from which point the two trains run over the same single line. Stealing a march having proved impossible, it only remained to see what could be done by sheer hard running. The East Coast train then excelled its previous record, but found the West Coast had again beaten it. This took place on Tuesday night of this eventful week. On Wednesday the East Coast got its head to the front and ran to Aberdeen, 523 miles in 520 minutes, while the West Coast was fifteen minutes behind. So confident were the East Coast authorities that this last performance could not be beaten, that they immediately put in hand the reconstruction of a most important bridge, which put further high speed on that line out of the question. But they had reckoned without their host. On Thursday night, the West Coast made a final effort and succeeded in reaching Aberdeen, 540 miles, in 520 minutes."* This gives a

* Ackworth—Railroad Gazette, August, 1895.

rate of 63.35 miles per hour, while the record of the recent run on the Lake Shore gives a record of 65.07. The English train weighed 75 tons, the American 150, both exclusive of engine and tender.

In passing it is well to note a word in regard to English signal practice, which it is the general belief of Americans who visited that country this summer, is not as efficient as the best practice here. The absolute block system prevails, the blocks being manually controlled. No electric locking is in use, except on certain lines south of London, where the Sykes system is somewhat used. Electric track circuits seemed unknown. Generally there is no check to a man giving a clear signal when the train is in the block, excepting his feel that he must not. Single lines are worked wholly by the staff or tablet; a runner being obliged to have this staff before he may proceed over a section, but these are often delivered and received at considerable speed.

The New Haven Road in this country is working with success, switches fifteen hundred feet from the tower, by the manual system, and signals two thousand feet, while the practice in England is never to locate a signal more than a thousand feet. The ordinary form of semaphore is in use, but it is pleasing to note that the white light for night signals has been abandoned. Red indicates "stop," green "safety," and no caution signals are in use. If they are not needed with the dense traffic in England, it would seem as if we should be able to avoid their use in this country.

A few words only are necessary about the organization of an English railway. Officials under somewhat different names, perform the duties of officials here. The Board of Directors is large, but it is an active Board, both as whole and through the sub-committees, which are frequently in session with the General Manager,—the General Manager himself carrying out the policy as outlined by the various committees. Inspector is a term frequently met with; it refers to a class of officers constantly on the line investigating the working of all departments and reporting the condition direct to the General Manager. In other words, they enable the General Manager's eye to be in many places at once. It would seem as if on our large systems, they would be of great assistance and relieve the Manager of much detail work now often neglected.

I may here mention two institutions which have an important bearing on the English practice. The one creation is of the railways, the other a medium between the people and the railway, both as to safety and tariffs. The English *Railway Clearing House* handles all the traffic relations between the railways, but does not deal with the public. It was established by Act of Parliament in 1842, being given powers by which it could sue under the name of its Secretary. Each railway and

steamboat in the United Kingdom Company has one representative of the General Committee. No company is forced to assent to any regulations that it does not desire to. The facility by which the auditing of this great traffic of upwards of a thousand million passengers and four hundred thousand million tons of freight annually are handled is interesting. Traffic confined to one road does not go through the Clearing House. The clearing house has an executive board which is in constant session at its headquarters in London, the Secretary being the active officer. Accounts are kept of upwards of two thousand pairs af stations, and the clerical force in the office and inspectors at junctions numbers upwards of two thousand. Demurrage and lost baggage are departments of the Clearing House, but especially its function is the interchange of traffic, passenger and freight. There is also connected with the Clearing House, an Employee's Pension Fund, which it is hoped will become universal, so that the individual corporation funds may be absorbed by it. This is under the supervision of a sub-committee, and does its work effectively.* It would seem as if our American lines would soon recognize, as have already two of them, the importance of making their employees feel that in old age they will be cared for, to make the love and interest of the corporation take the place of the mutual insurance companies and organizations, many of which are inadequately administered. The employee is but a human being, and if one will appeal to him and impress him that the corporation is his best friend, his loyalty can be assured with us as it is in England.

While the Railway Clearing House, as I have said, has no dealings with the public, the *Board of Trade*, by its regulations and special committees established in 1840, covers the relation. Rate making has been the subject of special Parliamentary commissions from time to time. In addition to individual inquiries, the Board of Trade prescribes certain rules in regard to signals, safety appliances, reports on important accidents, inspection of new property before it can be operated, and like duties. The cost necessitated by English standards of construction have virtually been prohibitive of the construction of light branch lines in the agricultural district of the United Kingdom. There is a strong effort being made to relax these standards to enable the construction of new secondary lines of this class. Mr. Bryce, the late President of the Board of Trade, has given this matter much personal attention.

Operating expenses on the leading lines average less than 55 per cent., but their large capitalization only enables them to pay about 6 per cent., and often less. There would seem to be nothing new or

* "The Railway Clearing House" and other pamphlets published by the Clearing House.

novel engaging attention, simply the minor improvements suggested by experience. Electricity is not yet a factor. English practice is unquestionably well adapted to English conditions, but save in a few details, it would not meet American demands, nor would our practice successfully meet English conditions.

A few remarks may now be in order as to the International Congress. The Congress held its first meeting in 1884 to commemorate the fiftieth anniversary of the opening of Belgian railways. At the call of the Belgian Government, delegates from the Government and Railway Administrations of Europe assembled at that time at Brussels, to discuss matters of interest in the working of railways. The Congress does not deal with what we understand to be traffic, but with transportation; nor does it prescribe standards or vote on questions except its own administration. Any railway in the world may become a member of the Congress through payment of a small annual due, receiving the *Congressional Bulletin*, which is of great value. It has met in Paris, Milan and St. Petersburg. Sessions are conducted in French, and in the language of the country in which it is held. This necessitated that the discussions in London be held jointly in French and English. The English-speaking representation is now so large that it is hoped that all publications heretofore only in French will be hereafter in French and English.

Wherever the Congress has met, it has received the hospitality, not only of the railways of the country, but of the Governments themselves. The Pennsylvania Railroad has, until of late, been the only American representative, but at the London session, some fifteen American companies had become members. The questions chiefly dealt with consist of those relating to permanent way, rolling stock, station service, signaling and general operation. In London the meetings were held at the Imperial Institute, a magnificent building near South Kensington Museum. The organization of the Congress consists of an Honorary President of the Session, which at the London session was His Royal Highness, the Prince of Wales; a President, which was Lord Stalbridge. There is an international Permanent Commission or an Executive Committee made up of prominent men from all nations, having a permanent president, M. Du Bois, the Chief Administrator of the Belgian State Railways. The five sections into which the Congress is divided for purposes of discussion have a chairman at each session.

Questions are submitted by the Permanent Commission to various authorities, whose reports are printed and distributed prior to the assembling of the Congress. These are supposed to be thoroughly read by the delegates, and on them the discussion is held. Certain conclu-

sions are expressed but are in no sense binding, and merely indicate the outcome of varied experience and views. At the London session nearly a thousand delegates from all parts of the world assembled. The next session of the Congress is to be held in Paris in 1900, but many of the Commission are extremely anxious that an intermediate session should be held in America, as the Congress has heretofore held sessions at from two to three years intervals. It would seem very desirable to those interested in the science of railways in this country, that they should endeavor to secure such session, as it would, without doubt, serve to eradicate certain notions of American practice in European minds. Possibly, then, we could persuade the Europeans that a steel fire-box will not leak; that an automatic signal is reliable, and a chilled wheel safe.*

I shall close with a short itinerary of the social features of the gathering. A number of the Americans left New York on the "City of New York," on the 10th of June, having an enjoyable trip. On arriving at Southampton, through the courtesy of the London and Southwestern Railway, a special train was placed at their service, carrying them quickly to London. Having arrived some time prior to the opening of the Congress, the party devoted their time to special excursions and sight-seeing. Their headquarters were at the Victoria Hotel, where the American Railway Association had provided parlors and a secretary. The opening ceremony took place on June 26th, at the Imperial Institute, presided over by the Prince of Wales, who made a most interesting address, and, in the course of his remarks, said:

"I have to discharge to-day a very pleasing and very important duty in declaring open the Fifth Session of the International Railway Congress. I fulfill this duty on behalf of the Queen, who takes great interest in the discussion of matters so closely affecting the welfare of her Dominion. I do so on my own behalf, being glad of the opportunity of expressing my deep appreciation of the Railway Authorities, and I perform it, finally, in the name of the great railway companies of this country, which are governed by men of highest ability and skill, who have asked me to be their spokesman. I welcome to England, the birthplace of railways, the delegates from the Continental States, and representatives, I think the first time in the history of these Congresses, from the two Continents of America. The last Congress, which assembled in St. Petersburg in 1892, was made memorable by the splendid hospitality

* Since the paper was read the letter of M. DuBois to Mr. Ely, of the Pennsylvania Railroad, indicating that under the rules it will now be impossible to arrange a meeting in the United States prior to 1900, but expressing a desire that the next meeting thereafter be held here, has been made public in *Proceedings of the Western Railway Club.*

and great encouragement given by the late lamented Emperor of Russia. I fear, we cannot promise you the beauties of Italy or the gayety of Paris, but we can show you Manchester, Liverpool, Cardiff and Crewe, great centers of industry, from which I hope you will be able to derive some useful knowledge. I venture to say this, even to our friends from the United States."

This address was followed by Mr. Bryce, President of the Board of Trade, the author of the "American Commonwealth," by M. Du Bois, and by Lord Stalbridge, the President of the Session, and Chairman of the London and Northwestern.

That evening a reception was tendered at the Foreign Office by Mr. Bryce, at which the Prince of Wales, his suite and many of the prominent men of English public life were present. The members of the Congress were next offered the hospitalities of the various English railway companies to make excursions of three days before the business sessions opened the following Monday. Excursions to the Severn Tunnel and the Welsh Coal Fields were offered by the Great Western to the Midland Counties by the Midland Company, to Darlington and the East Coast by the Great Northern, and to Crewe and beyond by the London and Northwestern. The party of the London and Northwestern consisted of nearly 200, leaving Euston by special train on Thursday morning, making the run of 156 miles with but one short stop at Rugby. The train was hauled by the engine "Greater Britain," Mr. Webb's well-known compound exhibited at Chicago, and run by the engineer who prides himself on saying that he is the only man who has run a train from Euston to Chicago, for you will remember that this engine ran to and from Chicago under steam. Directly behind the engine was placed the dynograph car, which indicates the work of the engine, and was followed with considerable interest by many of the delegates. Mr. Webb himself accompanied the train. The pull on the draw-bar as we left Euston was nearly ten tons, the train being composed of saloon carriages and dining cars, part of the regular West Coast Joint Stock. On reaching Crewe the delegates were shown through the works which are the headquarters of the mechanical part of this great system. Here rails are made and locomotives and signal apparatus, but the carriage or coach department has a separate establishment at Wolverton, and the wagon or freight car department at Earlstown near Liverpool. The party passed through the shops, absorbing as much as possible of the many interesting features. Sample engines of all types were drawn up on the track for inspection, and among others the "Charles Dickens," the engine most famous in the world for having made the great mileage of upwards of a million miles in less than ten years. In daily service to-day she runs from Manchester to London and back, a mileage of 366½.

The London and Northwestern Railway is the most important example of a corporation buying nothing but raw material. Whether on the whole it has been beneficial not to assist the great manufacturers along the line, and thereby get assistance from them in the way of traffic, is questionable. At Crewe works seventy-five hundred people are in constant employment. A lunch was served in the draughting office works, after which, further inspection being made, the party proceeded to Liverpool for the night.

The writer in company with two other Americans, desiring to make the most of his time, preceded the party to Liverpool and inspected that evening the Edge Hill yards. The next morning we started for Harwich to see the newest and, in many respects, the best railway shop in England, that of Lancashire and Yorkshire. Through the kindness of Mr. Aspinall, Superintendent of Motive Power, we were enabled to examine these shops more in detail than we could have done by waiting for the party, which would arrive there in the afternoon. This wonderful big little road has a mileage of 487 owned and running powers over 170 additional, all in the manufacturing and mineral regions of the counties of Lancashire and Yorkshire. It owns 1,200 locomotives, has a capital of £47,000,000, gross earnings £11,000,000 and expenses £6,000,000.

Two of us then proceeded across England, stopping two hours to visit the Royal Agricultural Show at Darlington, thence on to Edinboro; the next day across the Forth Bridge, and spending the day in the Highlands, returned to London on Monday morning, somewhat used up after a rough night on an antiquated Pullman car on the Midland from Glasgow. The roughness of riding of some of the English tracks is remarkable. The cars do not seem to curve with the ease that they should, though this was not as noticeable in the Pullman car as it was afterwards in a so-called sleeping saloon of the London and Northwestern.

The active work of the session began on Monday morning and continued every day for ten days. The sessions were of interest. Some delay was caused by interpreting into the other language, as the speaker might speak in French or English. However, having read the bulletins we were enabled to follow the conclusions with interest, if not the discussions. On Tuesday evening the first banquet was given by the English Railway Association at the Imperial Institute, presided over by Lord Stalbridge. After the customary toast to "The Queen," Lord Stalbridge, in proposing "The Guests," expressed pleasure at meeting on that occasion representatives of nearly every railway in the world. "The moment was a proud one for England, seeing that this was the first time that the representatives of the great railways of

the Western Continent had been present in such numbers with them, and he hoped that at some future time it would be their lot to be invited to the United States."

On Wednesday afternoon short excursions were provided out of London. The most interesting one to the speaker being that of the Canterbury Cathedral, as the guests of the London, Chatham and Dover. There we were met by the Bishop of Dover and shown through the cathedral and grounds, being given tea in the historic library. Returning in the evening, we were still the guests of the London, Chatham and Dover, at a banquet given at the Free Masons' Tavern. At the close of this banquet, I expressed a desire with several of the Americans, to see an English freight station at night. We proceeded to the Broad Street Station and there remained some time.

Thursday evening we attended a banquet of the American Society in London, being the Fourth of July. On Saturday Her Majesty tendered a garden party at Windsor Castle. Special trains were placed at the disposal of the Congress by the Great Western and South Western, which conveyed upwards of a thousand people. On arrival the guests were conducted through the state apartments, St. George's Chapel, and the Albert Memorial Chapel, and the grounds of the castle. Her Majesty, accompanied by their Royal Highnesses, Prince of Wales and other members of the Royal Suite, drove through the grounds, bowing to the assembled party. Later a small party of representative men from various parts of the world were presented to Her Majesty. During the afternoon two regimental bands were playing and a delightful tea was served in the garden.

The writer, being somewhat anxious to return, was unable to join the parties which left after the close of the session for Scotland and Ireland. Leaving London on Sunday, I journeyed by the London & Northwestern to Stranrear, there taking the short Irish Channel passage to Belfast, spending one day at the Giant's Causeway. The next day I left Belfast in the early morning on the Great Northern at seven, having a most enjoyable breakfast in the dining car on that line, arriving in Dublin in the forenoon; after some hours in that city I took the afternoon train for Cork, enjoying the picturesque Irish country. Next morning I proceeded to Queenstown and there found the "Majestic," arriving in New York just five weeks to the hour from when I had departed, having travelled some two thousand miles on English railways.

QUADRUPLE EXPANSION ENGINES FOR LAKE SERVICE.

By Walter Miller, Member of the Civil Engineers' Club of Cleveland.

[Read before the Club, January 14, 1896.*]

In August, 1885, the writer had the privilege of presenting to this Club a paper on the subject of compound engines for lake service. In that paper, predictions were made regarding the probable advance in marine engineering on the lakes within the next five years, an advance which would result in an increase of the steam pressures considerably above that deemed sufficient at that time, and in an extension of the application of the well-known principle of expansion, which has been largely the cause of the phenomenal increase of the tonnage on the great lakes. To what extent these predictions have been verified, will be seen.

When that paper was written, the steam pressures were limited, owing to the difficulties encountered in building boilers to carry a pressure much greater than 100 pounds per square inch. In the low pressure engines that had formerly been used for service on the lakes, any attempt to increase the steam pressures resulted in increased condensation and re-evaporation; besides augmenting to a great extent other evils incident to the increased number of expansions attempted in the single cylinder engine. In the compound system that had been introduced, the steam was expanded in two cylinders instead of in one, thus largely reducing the losses caused by condensation and re-evaporation. Besides, the economy of the steam consumed per indicated horse-power, was so clearly demonstrated that its further advance was seen to be, beyond all question, in the direction of a higher steam pressure and a further development of the well-known system of compounding.

In November, 1887, a little over two years later, the writer again had the privilege of presenting to this Club a paper on the subject of triple expansion engines for lake service. In this second paper, it was shown that the steam pressures had been increased from 100 to 160 pounds per square inch, and that this increase of pressure had resulted in the abandonment of the old fire-box boiler, so long in use for lake service, and had led to the adoption of the large plain shell internally fired, or Scotch boilers. For riveting, bending and drilling the heavy plates required for these boilers, heavy machinery had to be introduced

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to an extent little dreamed of in the early days of the lake marine; and the steam, instead of being expanded in one or two cylinders, was expanded in three, still farther reducing the losses caused by condensation and re evaporation. It was predicted also in this paper that a still further increase of pressures might be looked for in the near future, and that a further development of the principle of expansion would result in a further reduction of the steam consumed per indicated horse-power.

The paper that the writer has the honor to present to the Civil Engineers' Club of Cleveland to-night, treats of Quadruple Expansion Engines for Lake Service, thus marks a step further in the development discussed in the two earlier papers. In the present paper, it will be shown that the steam pressures have been increased from 160 to 195 pounds per square inch, and that the steam is now expanded in four cylinders instead of one, two, or three. In the fall ot 1892, the Northern Steamship Company, operating the Great Northern System of Railways in the Northwest, decided to build two fast express steamers for exclusives passenger service on the great lakes. These steamers were to run between Buffalo and Duluth, stopping only at Cleveland and Detroit, and touching at Sault Sainte Marie while passing through the rivers, canals, and lock between Lake Huron and Lake Superior, on their way to Duluth, where they connect with the great Northern System of railroads, mentioned above. After mature deliberation, and a large amount of preliminary work, it was finally decided to build two vessels, having an average speed of twenty miles per hour, and equipped with quadruple expansion engines and water-tube boilers.

The following table gives the dimensions of the hull, and other particulars:

Length over all	383	feet.
Length between perpendiculars	360	"
Breadth, moulded	44	"
Depth, moulded	26	"
Load draught	14	"
Load displacement	4,482	tons.
Tonnage, gross registered	4,244	"
Tonnage, net	2,340	"
Capacity of coal bunkers	1,000	"
Capacity of water bottom	680	"
Tonnage, cabin	442	"
Tonnage, steerage	211	"
Tonnage, crew	143	"
Tonnage, total	800	"

Figs. 1, 2, 3 and 4 are upper, saloon and main deck plans and profile of the vessel respectively, and show the general arrangement of cabin, state and dining rooms, space for crew, machinery, etc.

The vessels are driven by twin vertical quadruple expansion engines, with the high pressure cylinders forward, and with dimensions, etc., as follows:

Diameter of high pressure cylinders	25	inches.
Diameter of first intermediate	36	"
Diameter of second intermediate	51½	"
Diameter of low pressure	74	"
Stroke	42	"
Total I. H. P. of the two engines*	7,000	pounds.
Steam pressure	195	"

Speed of vessel at 120 revolutions of the engine per minute,* 20 miles per hour.

Number of propellers (cast iron)	2
Number of blades in each	4
Diameter	13 feet.
Pitch	18 feet 6 inches.

Boiler (Water Tube) Dimensions and Particulars.

Number in forward group	10	
Number in center group	8	
Number in after group	10	
Total	28	
Grate surface in one boiler	29	square feet.
Grate surface, total	812	"
Heating surface of one boiler	920	"
Heating surface, total	25,760	"
Ratio of heating surface to grate surface	31 to 1.	
Pressure allowed per square inch	267	pounds.
Total weight of engines and boilers	1,200	tons.

DESCRIPTION OF ENGINES.

Up to this time the use of quadruple expansion engines in this country was confined to yachts and other small steam crafts of high power and speed. The new American line steamships, "St. Louis" and "St. Paul," built by the William Cramp & Sons Ship and Engine Building Company, at Philadelphia, have quadruple expansion engines and Scotch boilers, but the steamers "Northwest" and "Northland" were the first vessels of great tonnage thus equipped. Their twin engines are of the vertical overhead cylinder quadruple expansion type, and were designed to develop 3,500 horse-power each, and to propel the vessel at an average speed of 20 miles per hour with 195 pounds of steam, the engines making 120 revolutions per minute.

The sizes of the cylinders as given above are 25 inches for the high,

* Estimated.

36 inches for the first, and 51½ inches for the second intermediate, and 74 inches for the low pressure, with a stroke of 42 inches. The high pressure cylinder is placed forward and is followed by the first and second intermediate and the low pressure cylinders. Piston valves are used throughout; one for the high pressure, and two each for the first and second intermediate and the low pressure cylinders. The valves are all arranged out-board on the working side, and all of them are operated by the Joy valve gear and reversed direct by steam and hydraulic gear. Where the valves are double, they are connected by a cross-head to which the radius rod of the valve gear is connected. The reverse arms are slotted and are fitted with blocks and adjusting screws. The engine columns, as shown in Fig. 5, are on the back or inboard side, and are of cast iron, forked, and of box section braced together with cast iron flanged distance pieces. The columns are fitted with detachable water-back guide faces. The columns of the front, or working side of the engine, are of wrought iron turned, to which are attached, by brackets, the reverse shaft and curved links for the valve gear. The cylinders are without liners or steam jackets, and the valve chests are connected by faced joints and by body-bound bolts. The low pressure and second intermediate cylinders are fitted with cone-shaped cast steel pistons, while the first intermediate and high pressure cylinders are fitted with cast iron pistons, all of which are completed with followers and single ring packing of cast iron, set out with flat bent springs. The piston rods are of steel, but do not extend through the top cylinder heads. The rods are secured to the pistons by quick taper and nut. The lower end is fitted with brasses, binder plate and bolts, forming the journal for the top end of the connecting rod. The cross-head, which is of the slipper pattern, is of cast iron and fitted with adjustable brasses, and is bolted to the piston rod. The connecting rod is of forged iron, with the lower end T-shaped, and is fitted with adjustable brasses lined with babbitt metal and secured to the rod by plates and bolts. In the middle of the connecting rod forged jaws are slotted out to receive the brasses to which are connected the vibrating levers of the valve gear. The upper end of the rod is forked and fitted with a steel pin that engages the cross head as already described. The bed plate is of cast iron and is made in four sections, planed and bolted together with body-bound bolts. The main journals in the bed plate are bored out and faced at the ends. Brass bushes, without flanges and lined with babbitt metal, are fitted into the bed plate, top and bottom alike, secured in place by cast iron liners, binders and bolts.

The thrust block is of the horse-shoe type, with cast iron adjustable shoes faced with babbitt metal. The shoes are adjustable, fore and-aft-wise, by thin nuts on two long screws, one on each side of the thrust

block. The sole plate of the thrust block is bolted to the bed plate on the after side. The total bearing of the main journals in the bed plate is 10 feet 8 inches. The intermediate bearings are lined with babbitt metal and placed at proper intervals to support the line shafts. Each crank shaft is built up in four duplicate parts. Each section is built up of two collared shafts, one crank pin and two crank slabs, all of forged iron, fitted and forced together by hydraulic pressure, and securely keyed. The length over all of each crank shaft for each engine is 22 feet 8 inches. The crank slabs are fiddle-shaped, 21 inch centers, $10\frac{3}{8}$ inches thick, and $27\frac{1}{2}$ inches diameter across the eye. The short sections of the collared shafts are $13\frac{3}{4}$ inches diameter in the bearing, $25\frac{1}{2}$ inches diameter at the couplings, and $14\frac{1}{2}$ inches diameter where they fit the eye of the crank slabs. The line shafting for each set of engines consists of five pieces, one thrust shaft 13 feet $8\frac{1}{2}$ inches long, $13\frac{1}{2}$ inches in diameter in the body, and $13\frac{3}{4}$ inches diameter in the bearing, and 20 inches diameter of thrust collars with flanges of same dimensions as those on the crank shaft. The first and second lengths of the line shaft are 20 feet $\frac{1}{4}$ inch long each, and the third section is 25 feet $\frac{1}{4}$ inch long, all $13\frac{1}{2}$ inches in diameter in the body of the shaft and $13\frac{3}{4}$ inches diameter at the bearings, with solid forged couplings of same dimensions as those on the crank shaft. The propellor shaft is 22 feet 1 inch long over all, $13\frac{3}{4}$ inches to $13\frac{5}{8}$ inches in diameter, and is covered with a brass sleeve 56 inches long at the bearing in the stern tube. This makes the total length of shafting, including the crank shaft, 123 feet 6 inches for each engine. The propellors are four bladed, sectional wheels of cast iron, made right and left, 13 feet diameter, with an expanding pitch of 18 feet 6 inches, and fitted to the shaft by taper, key and nut.

As previously stated, the valves are operated by the Joy valve gear, in which the valves obtain their movement from a combination of two motions, one being taken from the connecting rod at a point near the middle of its length and the other from a pair of curved links. This combination of levers for operating the valves is so proportioned, from the point of connection with the connecting rod, that the short end of the lever has a movement equal to that required for the laps and leads of the valves of the cylinders. The cross-head that forms the fulcrum for the short end of the lever, works in two curved links which are pivoted to the bearings on the front of the engine. These links are curved to a radius equal to the length of the valve rod. Thus it will be seen that when the curved links are at right angles to the valve rod, the valves have a motion equal to the laps and leads only, and that the required port opening is obtained by tipping or rolling the curved links up or down, as the case may require, corresponding to the go-ahead or backing position. The lower ends of the curved links are connected

to the blocks in the slotted reverse arms by two short eye bars. Hence the point of cut-off can be regulated to any desired extent by the adjusting screw in the reverse arms. The main reason for adopting the Joy valve gear in this case was to reduce the fore-and-aft length of the engines, as this arrangement renders it unnecessary to provide room for eccentrics or space between cylinders for valve chests. Besides, the lead remains constant at all points of cut-off.

The engines are fitted complete with relief valves at each end of each cylinder and in the receiver chests. Drain valves are fitted to the bottoms of the cylinders and value chests.

The air pumps and condensers are detached and are worked independent of the main engines. They are of the jet condensing vertical compound direct connected type, with a high pressure cylinder 15 inches and a low pressure cylinder of 30 inches bore, and a stroke of 18 inches. The air pumps are single-acting, 38 inches bore by 18 inches stroke. The piston rods of the steam cylinders are continuous into the air pump, and the high and low pressure cylinders are connected together by double beams linked to cross-heads keyed to the piston rods. The condenser is bolted on the side of the channel plate, and is fitted with cone, spray nozzles, injection valves, etc. The feed pumps are located in the engine room and are quadruple, with double-acting steam cylinders and single-acting water plungers. All are connected by cranks and fly wheels. The cold water bilge, ballast and sanitary pumps are of the duplex type and are all located in the engine room.

To sum up, there are twenty-one pumps with twenty eight steam cylinders and twenty-two water cylinders, six centrifugal pumps and nine other engines with sixteen steam cylinders and six blowers. If we include three electric plants, with their three engines and air pumps, and the main engines with their eight steam cylinders, there are in all sixty-five steam cylinders and twenty-six pump cylinders on board the "Northwest."

It is in the steam generating plant that there is the greatest departure from existing methods, and time alone will determine whether these will prove suitable for general use in the merchant marine. The boilers were invented by M. Belleville, of the firm of Delauney, Belleville & Co., of St. Denis, Seine, France, and were introduced in this country by their agent, Mr. Miers Coryell, of New York. There are in the steamer "Northwest" twenty-eight Belleville patent water tube boilers, which are divided into three groups. They were designed to generate steam sufficient for the main engines to indicate 7,000 horse-power and for auxiliary machinery 500 horse-power motor with natural draught. Fig. 6 shows the front and side of one generator, and Fig. 7 shows one of the boiler rooms, with a group of four boilers. The boilers are joined together

back to back in-board, directly over the keel line of the hull. They occupy the center of the vessel, one-half of each group facing out-board and then come the fire rooms, one on the port side and the other on the starboard side. Outside of the fire rooms, and extending to the sides of the vessel, are the coal bunkers. The boilers are entirely below the main deck. The groups are so arranged that there are ten boilers in the forward fire room, eight in the middle and ten in the after one. Each group has its own smoke funnel, and each has two fire rooms connected by a cross passage. The boilers are 12 feet 9 inches and the fire rooms 6 feet 7½ inches, athwartships from face to face. The outer limits of the fire room are the fore-and-aft bunker bulkheads, which are 26 feet apart; and, as the extreme beam of the vessel is 44 feet, there is left for bunker space 9 feet at the widest part. The bunkers will store about a thousand tons of coal. The three groups of generators, the cross passages and the fire rooms occupy a floor space 26 feet wide by 124 feet long. The extreme height of the boilers is 11 feet.

As before mentioned, the total grate surface in each boiler is 29 square feet, and the total for the twenty-eight boilers is 812 square feet of grate, while the heating surface in one boiler is 920 square feet, and the total heating surface in the twenty-eight boilers is 25,760 square feet. The ratio of heating to grate surfaces is 31 to 1, the maximum pressure allowed is 267 pounds per square inch, and the total weight of the boilers, with water, is 400 tons. The grates are of the Ætna shaking pattern.

As will be seen from the illustrations, each boiler consists of a series or set of tubes or elements placed side by side over the fire and enclosed in non conducting casings. Each element is in the form of a flattened spiral, and consists of straight tubes connected at the ends by junction caps of malleable cast iron. The caps are placed vertically one above the other, and the upper end of one tube is on the same level as the lower end of the one above it. Holes, provided with doors, cross bars and bolts, are fitted in the front caps for inspection and cleaning. The tubes are slightly inclined to the horizontal, and the lower caps of each element are connected at the front of the boiler with a horizontal cross tube called the feed-collector tube. The upper tube is connected to the lower part of a cylindrical steam receiver placed outside of the boiler casing. A vertical circulating pipe, also placed outside the casing, conveys the down current to a mud drum placed at the base of the boiler, the upper part of which is connected to the feed collector. The feed water is delivered into the steam receiver at the ends remote from the inlet of the downcast pipe. Thence it runs along the receiver bottom, down the external pipe, through the mud drum and into the feed collector, and thence into the several elements to be heated by the

action of the fire, on its upward way through the tubes, from which it emerges into the receiver a mixture of water and steam. Here the steam is separated, by suitable baffle and dash plates, from the water, which, with the addition of the fresh feed water, again passes along the receiver bottom to the downcast pipe, and follows the same course as before. The feed water is supplied by the feed pump, and its admission to the receiver is regulated by a self-acting gear of novel design. The water stand-pipe is connected to the top and bottom caps of the outside elements, and in it is pivoted a float which rises and falls with the level of the water in the stand-pipe, opening and closing, by means of suitable gear, a balanced feed-check valve of special design fitted on to the receiver. The water-level in the stand-pipe is maintained at a constant height, which, when the boiler is under pressure, with the tubes full of a mixture of steam and water, is on a level with the fourth tube from the top. The forced circulation of water is caused by the difference in density between the water in the downcast pipe and the mixture of the steam and water in the element tubes. On leaving the receiver, the steam is led through a separator formed with a self-acting trap.

One of the main features of the Belleville system is that the boiler pressure should be considerably in excess of the working pressure of that required for the engines, to which it is reduced by means of a suitable reducing valve. The reason for M. Belleville's preference for very high pressures is that, besides increasing the economy of evaporation, it facilitates the separation of the earthy salts contained in the feed water. The solubility of these salts decreases as the temperature of the water increases, and here we have the reason for introducing the feed water at the ends of the reservoir remote from the downcast pipes, and leading it through the entire length of the receiver. The salts, which are principally sulphates and carbonates of lime, are precipitated, and fall to the bottom of the sediment chambers or mud drums, whence they are blown off as often as required. The time required for raising steam is, of course, extremely short.

This is a description of the motive power of the steamers "Northwest" and "Northland," and, while many of the members of this Club saw the second set of machinery nearly finished in the erecting shops of the builders, and a few had the opportunity of seeing the engines in motion on some of the initial trips, yet to those that have not had these opportunities some further description is necessary to a full understanding of the principles involved. The steam is admitted to the high pressure or forward cylinder, and is cut off at about $\frac{4}{10}$ of the stroke, expansion taking place during the remainder of the stroke. The steam is then exhausted into the receiver space between the first and second cylinders, and from this space it is admitted to the first intermediate

cylinder and is cut off in the same manner as in the high pressure cylinder. It continues through the second intermediate cylinder to the low pressure cylinder, whence it is exhausted into the condenser. It will be seen that with a $\frac{4}{10}$ cut-off in the high pressure cylinders, and a cylinder ratio of 8.07 from the high to the low pressure, the number of expansions would be over twenty. The steam is not admitted to the high pressure cylinders at the full boiler pressure, but is reduced from about 225 to 195 pounds per square inch by means of a reducing valve under the control of the engineers. As has already been explained, the steam, as fast as it is generated, passes up through the flattened spirals of the several elements on its way to the steam receiver, carrying with it large quantities of water from which it has to be separated. This is accomplished by baffle plates and screens arranged in the steam drum or receiver, and the process of separation is further assisted by the steam in the boiler being kept at a greater pressure than that delivered to the engine; in other words, by reducing as much as possible the velocity of the steam in the main steam pipe, on its way to the engines, by means of the large reducing valves already referred to.

The sequence of the cranks are: low leading, followed by the second and first intermediate and high pressure. The reduction of the extreme weights between the high and low pressure pistons is greatly assisted by making the low pressure and second intermediate pistons of cast steel, and the first intermediate and high pressure pistons of cast iron, while the high pressure piston is solid, and the first intermediate piston nearly so. With the sequence of cranks as described, the low pressure and first intermediate pistons are diametrically opposite and of nearly the same weight, while the second intermediate and high pressure pistons are opposite and of nearly the same weight, making a very evenly balanced engine. It can thus be turned up to a high rotative speed in order to obtain the piston velocity required, and this is accomplished with but little vibration. With such high steam pressure great care and good judgment must be used in arranging the piping and valves. All the joints are flanged and made male and female. Otherwise the high steam pressures can be used with very little difficulty

The most interesting part of this subject is yet to be touched upon, viz., what economy has been effected by the increased steam pressures carried and by these improved methods of working the steam expansively. Owing to the wide difference in the systems to be tested, and in the conditions under which the tests must be made, it is not possible to estimate the economy with any degree of accuracy by tests, except in a general way. In making such an estimate, we must consider to what extent, if any, and to what parts, steam jacketing had been applied, or whether the receivers were or were not furnished with re-heaters, their size and

location, the sequence of cranks, whether the engines are for land or marine service, under what conditions the tests were made, the design of the steam generators used, whether these are externally or internally fired, water-tube or otherwise, their evaporative equivalent and many other conditions, besides making due allowances for inaccuracies in the instruments or errors on the part of assistants. These are usually unknown quantities until after the test is made and the results are figured up, and they are then made large or small or according to the interest of the parties making the guarantee. Thus it will be seen that while tests are made to determine the relative efficiency of engines and boilers for the lake service, and while they are as accurate as circumstances will permit, and of value in determining to what extent improvements on any system in use are, or can be made, their results can show only in a general way what is being accomplished. Tests made in each individual case cannot be accepted as conclusive, nor will the summations prove beyond all question that the results may not be different under different conditions. The figures given below show the average economies of the different systems, based on the result of numerous observations and actual tests made, and are not to be taken as representing the best that has been done in either of the systems.

System.	Steam Pressure.	Steam consumed per indicated horse-power.
Low pressure	60 pounds per square inch	36 pounds
Compound	100 " " " "	16 "
Triple expansion	160 " " " "	12 "
Quadruple expansion . . .	195 " " " "	11 "

In other words, the economy of the compound system over the low pressure is 55 per cent.; that of triple expansion over the compound is 24 per cent.; and that of quadruple over triple expansion is 10 per cent.

The writer is indebted to the editors of the *Marine Review* for the use of the plates from which the illustrations are printed.

DISCUSSION.

Mr. Joseph R. Oldham.—I rise with pleasure to congratulate Mr. Miller on his excellent work connected with the boilers and machinery of the "Northwest. "When we consider the exigencies of the trade in which that steamer and her sister, the "Northland" have engaged, it will at once be evident that the designing and construction of such vessels on these lakes was a great achievement. Although the design of the boilers was not Mr. Miller's, he had the responsibility of

their arrangement in the steamer, and, though the design is French, the workmanship is purely American, for I believe that every pound weight of those boilers was made in Cleveland, O. The problem facing the designer of the "Northwest" was a most difficult one, for throughout a great part of the voyage the most suitable steamer would be a side-wheeler, such as the "City of Detroit," whilst a small Atlantic liner would not be too large nor too staunch for the Fall trade in Lake Superior. The "Northwest" did her season's work without losing a trip, and this achievement redounds with unalloyed credit to the designers and builders.

As Mr. Miller's paper is on quadruple expansion, it may be well for us to consider the object in view in adopting multiple expansion. The economy resulting from the adoption of triple or quadruple expansion lies in limiting and lessening the range of temperature. For instance, look at the old one-step condensing engine. The range of temperature was generally over one hundred degrees, and when pressures went up, the heat did not rise in anything like an equal ratio. Consequently, by dividing the expansion into three or four steps, we reduce the range of temperature in each cylinder by about one-half; but it should be borne in mind that the principle of expansion is the same, whether steam be expanded in one or in any number of cylinders.

The energy exerted by a fluid depends on the change in temperature and in volume which it undergoes and not on the number and arrangement of the cylinders. For instance, the bulk of the steam in the "Northwest's" high-pressure cylinder at the instant of cut-off would exert the same amount of energy if passed directly into the low-pressure engine as it does after passing through all the cylinders, although this is of course modified by the cylinder condensation and re-evaporation.

Let me say a word about the Scotch boiler, and I have done. I would not like to see such a safe, reliable and useful old friend depart, if go it must, without a hearty farewell; and, with a view to its retention as long as possible, I think this Club might press upon our Inspectors the necessity for relaxing their rules with regard to the cylindrical shell. I never knew of a marine boiler shell exploding, and when I add that the shells of our boilers are about 50 per cent. heavier than the British Admiralty require for immense fleets, you will surely agree with me that we might reduce the thickness of our boiler shells with advantage and without running any undue risk.

Mr. Richard L. Newman.—I congratulate the author of the paper just read, and I congratulate the city of Cleveland on the possession of such an able engineer. Mr. Oldham has just remarked that he thinks the Scotch boiler will remain with us for a number of years yet, but I must differ from him on this point, as I believe we shall, in a very short time,

UPPER DECK PLAN

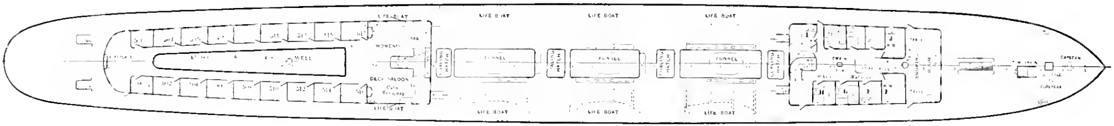


FIG. 1.

SALOON DECK PLAN

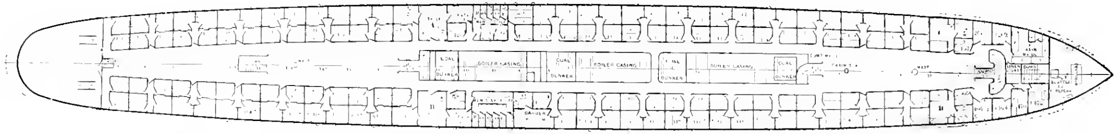


FIG. 2.

MAIN DECK PLAN

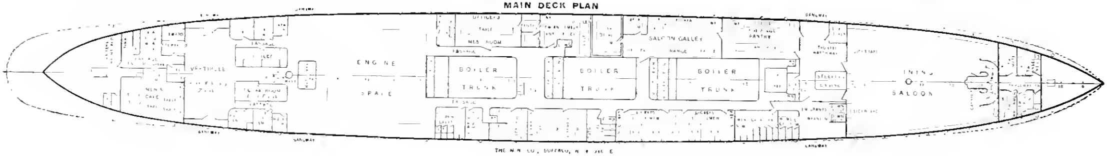


FIG. 3.

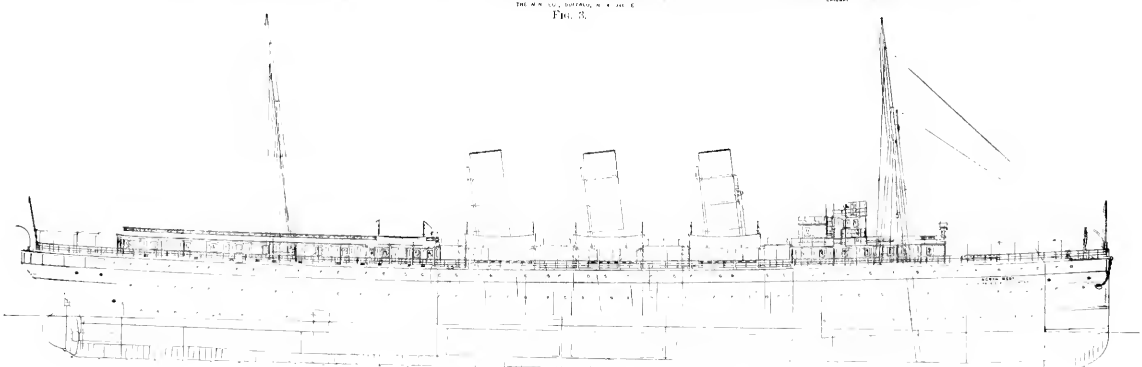


FIG. 4

PLATE I.

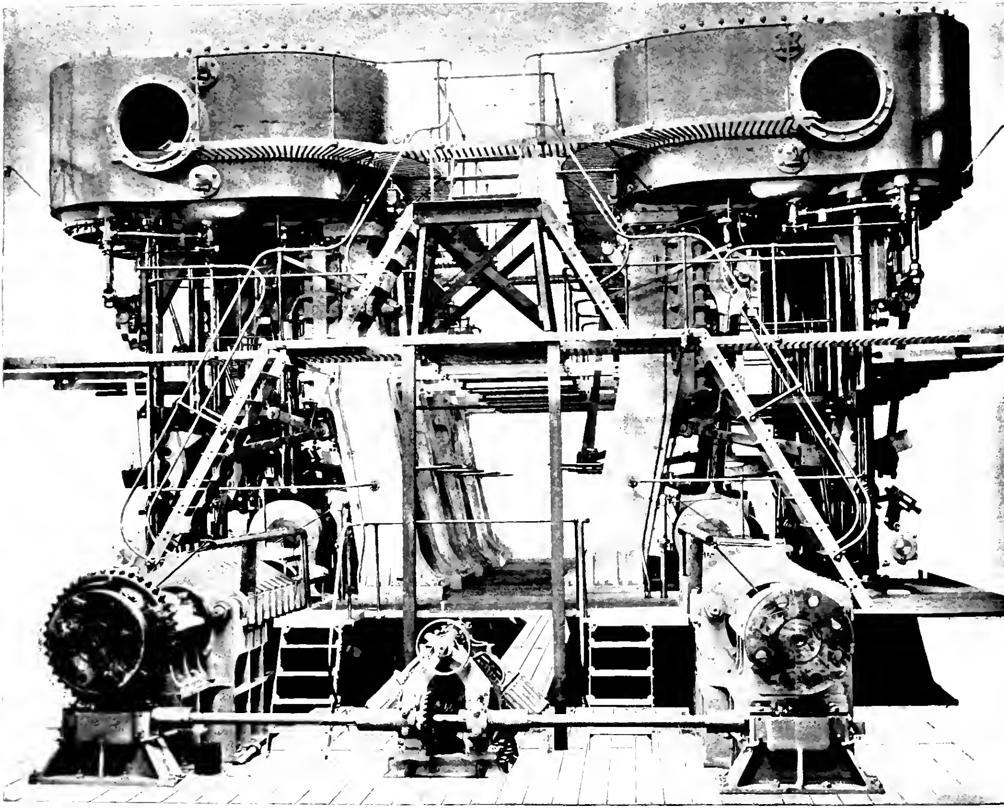
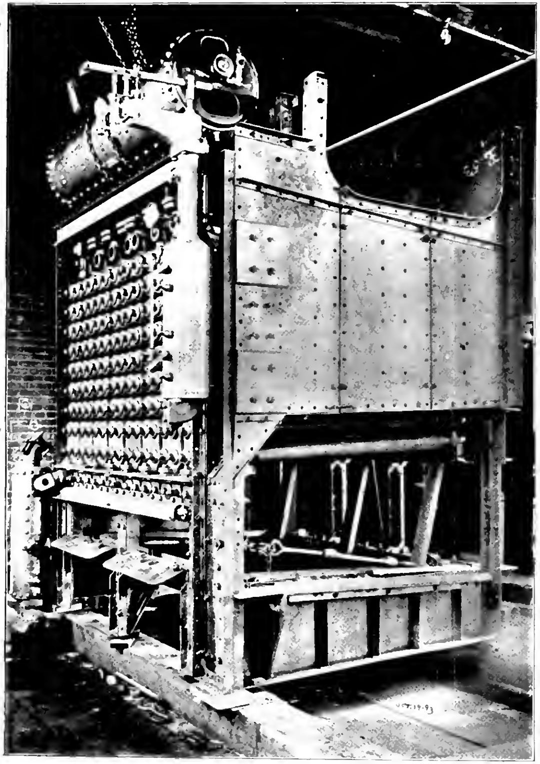


FIG. 5.—QUADRUPLE EXPANSION ENGINES, STEAMSHIP "NORTHWEST."

[illegible]00 indicated horse-power. Cylinders 25, 36, [illegible], and 74 by 42 inches. Steam furnished by twenty-eight Belleville boilers.



IN PROCESS OF CONSTRUCTION, SHOWING FIRE SPACE AND TUBE ENDS

Fig. 6

IN ONE OF THE BOILER ROOMS, SHOWING A GROUP OF FOUR BOILERS

Fig. 7

BELLEVILLE WATER TUBE STEAM GENERATORS

[illegible] Heating surface [illegible] square feet. [illegible] complete with water, 812,000 pounds.

PLATE III.

see very rapid progress in the adoption of the water-tube boiler. Mr. Miller in his remarks referred to the "St. Louis" and the "St. Paul," and in this connection I think we might, with advantage, make a few comparisons. The weight of machinery, as given by Mr. Miller for the "Northwest," was 1,200 tons for 7,000 indicated horse-power. The former gives us 5.9 indicated horse-power per ton of weight. That of the latter ships is 6.66 indicated horse-power per ton of weight. This, to me, is rather a surprise, as I would naturally look to the application of the water-tube boiler as resulting in a saving of weight, in addition to its ability to carry a higher steam pressure; but here we have Scotch boilers showing quite as good results, if not better, than those of the Belleville boiler.

Quite recently I was engaged on several schemes in connection with the proposed battleships Nos. 5 and 6. Here we proposed to fit a Niclausse water-tube boiler and expected a saving, in regard to weight carried, of about 40 per cent. Our estimates on the Yarrow boiler promised quite as liberal results In support of this I quote the French cruiser "Friant." This boat was fitted with a battery of twenty Niclausse boilers, and developed, on trial, an aggregate horse-power of 9,500. The weight of these boilers was, with water and all fittings, about 260 tons. The estimated weight of a battery of Scotch boilers, for the same power, would be about 500 tons, which, as you see, is greatly in excess of the weight of the water-tube boiler.

One gentleman desired to know the effect of the application of the reducing valve between the boiler and the engine. In 1886, I was engaged on the designs of a torpedo gunboat for the Russian government. This boat was fitted with a battery of Belleville boilers. I think the general impression then was that the reducing valve tended to dry the steam, that is to say, that, owing to the fact that the steam expanded without doing external work, the extra heat was absorbed by the steam and tended to superheat it.

I agree, also, with Mr. Oldham in his remarks as to the strength of the boiler shell being in excess of that actually required; for a number of years I have been engaged in both the designing and construction of boilers, where we allowed a factor of safety of not more than four. One of these boiler shells was subjected to water pressure, and was found to be practically indestructible, so far as the testing machinery then at hand was concerned. This, then, seems to show that a factor of four is quite sufficient for a boiler. In answer to your respected Secretary, I would say that there is not the slightest doubt in my mind that the machinery of the "St. Louis" and "St. Paul" is the finest on any trans-Atlantic liners now running.

I thank you for the courtesy extended to a stranger, in permitting him to join in this most interesting discussion.

ASSOCIATION OF ENGINEERING SOCIETIES.

Articles of Association.

The following Articles of Association were adopted at a meeting held in Chicago, December 4, 1880. At this meeting there were present representatives of the

Western Society of Engineers,
Civil Engineers' Club of Cleveland,
Engineers' Club of St. Louis;

and the

Boston Society of Civil Engineers

was represented by letter.

FOR THE PURPOSE OF SECURING THE BENEFITS OF CLOSER UNION AND THE ADVANCEMENT OF MUTUAL INTERESTS, THE ENGINEERING SOCIETIES AND CLUBS HEREUNTO SUBSCRIBING, HAVE AGREED TO THE FOLLOWING

ARTICLES OF ASSOCIATION.

ARTICLE I.

NAME AND OBJECT.

The name of this Association shall be "THE ASSOCIATION OF ENGINEERING SOCIETIES." Its primary object shall be to secure a joint publication of the papers and transactions of the participating societies.

ARTICLE II.

ORGANIZATION.

SECTION 1. The affairs of the Association shall be conducted by a Board of Managers under such rules and by-laws as they may determine, subject to the specific conditions of these articles. The Board shall consist of one representative from each society of one hundred members or less, with one additional representative for each additional one hundred members, or fraction thereof over fifty. The members of the Board shall be appointed as each society shall decide, and shall hold office until their successors are chosen.

SEC. 2. The officers of the Board shall be a chairman and secretary, the latter of whom may or may not be himself a member of the Board.

ARTICLE III.

DUTIES OF OFFICERS.

SECTION 1. The Chairman, in addition to his ordinary duties, shall countersign all bills and vouchers before payment and present an annual report of the

transactions of the Board; which report, together with a synopsis of the other general transactions of the Board of interest to members, shall be published in the Journal of the Association.

SEC. 2. The Secretary shall be the active business agent of the Board and shall be appointed and removed at its pleasure. He shall receive a compensation for his services to be fixed from time to time by a two-thirds vote. He shall receive and take care of all manuscript copy and prepare it for the press, and attend to the forwarding of proof-sheets and the proper printing and mailing of the publications. He shall have power, with the approval of any one member of the Board, to return manuscript to the author for correction if in bad condition, illegible, or otherwise conspicuously deficient or unfit for publication. He shall certify to the correctness of all bills before transmitting them to the chairman for countersignature. He shall receive all fees and moneys paid to the Association and hold the same under such rules as the Board shall prescribe.

ARTICLE IV.

PUBLICATIONS.

SECTION 1. Each society shall decide for itself what papers and transactions of its own it desires to have published and shall forward the same to the Secretary.

SEC. 2. Each society shall notify the Secretary of the minimum number of copies of the joint publications which it desires to receive, and shall furnish a mailing-list for the same from time to time. Copies ordered by any society may be used as it shall see fit. Payments by each society shall in general be in proportion to the number of copies ordered, subject to such modification of the same as the Board of Managers may decide, by a two-thirds vote, to be more equitable. Assessments shall be quarterly in advance, or otherwise, as directed by the Board.

SEC. 3. The publications of the Association shall be open to public subscription and sale, and advertisements of an appropriate character shall be received, under regulations to be fixed by the Board.

SEC. 4. The Board shall have authority to print with the joint publications such abstracts and translations from scientific and professional journals and society transactions, as may be deemed of general interest and value.

ARTICLE V.

CONDITIONS OF PARTICIPATION.

SECTION 1. Any society of Engineers may become a member of this Association by a majority vote of the Board of Managers, upon payment to the Secretary of an entrance fee of fifty cents for each active member, and certifying that these Articles of Association have been duly accepted by it. Other technical organizations may be admitted by a two-thirds vote of the Board, and payment and subscription as above.

SEC. 2. Any society may withdraw from this Association at the end of any fiscal year by giving three months' notice of such intention, and shall then be entitled to its fair proportion of any surplus in the treasury, or be responsible for its fair proportion of any deficit.

SEC. 3. Any society may, at the pleasure of the Board, be excluded from this Association, for non-payment of dues after thirty days' notice from the Secretary that such payment is due.

ARTICLE VI.

AMENDMENTS.

These articles may be amended by a majority vote of the Board of Managers, and subsequent approval by two-thirds of the participating societies.

ARTICLE VII.

TIME OF GOING INTO EFFECT.

These articles shall go into effect whenever they shall have been ratified by three societies, and members of the Board of Managers appointed. The Board shall then proceed to organize, and the entrance fee of fifty cents per member shall then become payable.

These articles were adopted by the several societies upon the following dates:

Engineers' Club of St. Louis, January 5, 1881.
Civil Engineers' Club of Cleveland, January 8, 1881.
Boston Society of Civil Engineers, January 19, 1881.
Western Society of Engineers, April 5, 1881.

The Board of Managers was organized at Cleveland, January 11, 1881.

The following societies have since certified their acceptance of the Articles, and have become members of the Association of Engineering Societies:

Engineers' Club of Minneapolis, July, 1884.
Civil Engineers' Society of St. Paul, December, 1884.
Engineers' Club of Kansas City, January, 1887.
Montana Society of Civil Engineers, April, 1888.
Wisconsin Polytechnic Society, June, 1892.
Denver Society of Civil Engineers, January 24, 1895.
Association of Engineers of Virginia, February 1, 1895.
Technical Society of the Pacific Coast, March 1, 1895.

The Wisconsin Polytechnic Society withdrew from the Association in March, 1894.

The Western Society of Engineers withdrew in December, 1895.

Annual Report of the Chairman of the Board of Managers.

St. Louis, December 31, 1895.

To the Members of the Board of Managers of the Association of Engineering Societies.

Gentlemen:—In submitting to you herewith the report of the Secretary of the Association, I desire to call your attention to the apparent excess of our assets over our liabilaties for the year of $223.73. The recent withdrawal of the Western Society of Engineers, from the Association, would seem to entitle them to their portion of this excess, but inasmuch as $316.55 of these assets consist of subscriptions overdue, and of accounts for sales and advertisements, on which some considerable loss must be anticipated, it is evident that no final settlement with the Western So-

ciety for a credit to them of any portion of this apparent excess can be made at this time.

So far as I know there is now perfect harmony between the various societies belonging to the Association, and an entire satisfaction on their part with the management of the affairs of the Association by the Board. The Chairman wishes again to publicly acknowledge the valuable service of our efficient Secretary and to solicit in his behalf the cordial assistance not only of the members of the Board, but of the officers and members of the several societies in the Association. His services to the Association cannot be measured by the meager salary which we can afford for this work.

The Chairman bespeaks, also, for the editor of the *Engineering Magazine*, such assistance on the part of the Board, and of the officers of the several societies, as will enable him to successfully supply the members of these societies with copies of the bound volume of Index Notes which have appeared in our JOURNAL for the past four years, and which he will supply to the members of the societies in the Association at the price of $2.50 each, whereas the price to all other parties will be $4.00. The Chairman has assured him that no undue advantage will be taken of this reduced rate to our own members, and furthermore that the officers of the several societies would assist him in carrying out this business arrangement. It is hoped also that those of our readers who have valued our Index Department will subscribe for the *Engineering Magazine*, in which this department will be maintained on a much more elaborate scale, and so remunerate the editor of that Journal for the great additional expense involved in its adoption of our style of index.

The Chairman wishes also to thank the members of the Board and the officers of the various societies in the Association, for their courteous and considerate acquiescence in such executive decisions as he has been called upon to make. In the absence of meetings of the members of the Board, it is often impractical to submit questions to the entire Board for decision, and many things have thus to be determined by the Chairman and Secretary on their own responsibility. During the past two years a much larger amount of business has come before the Board than in any similar period before, and yet no meeting of the Board has been held. The Chairman bespeaks, therefore, for Mr. S. E. Tinkham, of Boston, the Chairman elect, the same spirit of helpful compliance which they have shown to their retiring Chairman.

Respectfully submitted,

J. B. JOHNSON, *Chairman.*

Annual Report of the Secretary of the Board of Managers.

PHILADELPHIA, DECEMBER 31, 1895.

Prof. J. B. Johnson, Chairman.

WASHINGTON UNIVERSITY, ST. LOUIS, MO.

DEAR SIR:—I have the honor to present the following report upon the operations of the Secretary's office during the year 1895, and of the condition of the Association at the present time.

The following is a statement of the receipts and expenditures during 1895:

CASH, 1895.

Dr.

To Balance, January 1, 1895	$330 44		
" Initiation Fees:			
Denver Society of Civil Engineers	13 50		
Association of Engineers of Virginia	17 50		
Technical Society of Pacific Coast	80 00		
		$111 00	
" Assessments:			
Boston Society of Civil Engineers	1,043 56		
Western Society of Engineers	1,475 25		
Civil Engineers' Club of Cleveland	663 78		
Engineers' Club of St. Louis	629 11		
Civil Engineers' Society of St. Paul	119 37		
Engineers' Club of Minneapolis	123 25		
Engineers' Club of Kansas City	100 00		
Montana Society of Civil Engineers	165 72		
Denver Society of Civil Engineers	88 85		
Association of Engineers of Virginia	102 75		
Technical Society of the Pacific Coast	292 75		
		4,804 39	
" Subscriptions		594 14	
" Sales of JOURNALS		247 36	
" " Descriptive Index, 1884–91		40 00	
" Advertisements		679 84	
" Sales of Reprints		264 25	
" Interest on Deposits		3 63	
" Postage refunded		3 72	
			$7,078 77

Cr.

By Edward Stern & Co., Incorporated (Printers)	$4,700 00	
" Illustrations	716 39	
" Secretary's salary	600 00	
" Linotype composition	197 00	
" Index compilation, 1894	175 00	
" Traveling expenses	145 66	
" Car fares	4 96	
" Typewriting, etc.	20 75	
" Mimeographing	38 90	
" Advertising	8 32	
" Discounts on subscriptions	18 41	
" " sales	3 75	
" Commissions on advertisements	80 75	
" Allowance to Western Society of Engineers, account T. L. Condron	1 50	
" Messenger service	13 64	
" Stationery	13 15	
" Telegrams	8 42	
" Postage stamps	42 07	
" Affidavit	1 00	
" JOURNALS bought	3 50	
" " returned	30	
" Directing envelopes	6 00	
" Express and freight charges	10 57	
		$6,810 04
" Cash Balance December 31, 1895		$268 73

Estimate of Assets and Liabilities at the Close of 1895.

AVAILABLE ASSETS.

Cash balance December 31, 1895		$268 73	
Less subscriptions for 1896 paid during 1895		34 25	
			$234 48
Amounts receivable from Societies (for assessments, etc.):			
Boston Society of Civil Engineers	308 10		
Western Society of Engineers	47 25		
Civil Engineers' Club of Cleveland	4 00		
Engineers' Club of Minneapolis	77 28		
Engineers' Club of Kansas City	134 01		
Montana Society of Civil Engineers	48 00		
Association of Engineers of Virginia	6 75		
Technical Society of the Pacific Coast	122 50		
		747 89	
Subscriptions due:			
For 1895	41 50		
" 1894	24 00		
" 1893 and earlier	12 00		
		77 50	
For Reprints		158 30	
" Advertisements		97 00	
" Sales of Journals		12 25	
" Sales of Index, 1884–91		12 00	
" Linotype metal		58 40	
			$1,163 34
			$1,397 82

LIABILITIES.

Edward Stern & Co., Incorporated (Printers):			
Ledger balance	$200 85		
For December Journal	539 34		
" Reprints, 1895	70 00		
		$810 19	
Bradley & Poates:			
Wax process, engravings		82 00	
Burk & McFetridge:			
Photolithography		69 00	
Philadelphia Inquirer Co.:			
Linotype Composition		15 43	
Philadelphia Typewriter Exchange		8 52	
J. B. Johnson, Index Compilation, 1895		175 00	
Engineers' Club of St. Louis		9 75	
Civil Engineers' Club of Cleveland		4 00	
			$1,173 89
Excess of Assets over Liabilities			$223 93

The deficit of $758.91, existing at the close of 1894, was covered by an extra assessment of 66 cents per member.

Cost of JOURNAL During 1895.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Composition.	Paper, Presswork, Binding.	Wrapping, etc.	Postage.	E. Stern & Co. Sum of 1, 2, 3 and 4.	Illustrations.*	Index Compilation.	Cost of Manufact'e Sum of 1, 2, 6 and 7.	Wrappers.	Secy's Salary.	Sundries.†	Total.	No.‡ of Pages.	Cost per Page.
January . .	$188 53	$231 00	$6 50	$14 64	$440 67	$105 75	$14 58	$539 86	$5 36	$50 00	$42 09	$658 45	162	$4 06
February	120 89	168 60	6 19	12 33	308 01	39 50	14 58	343 57	5 37	50 00	42 09	459 55	118	3 89
March	160 49	239 60	6 74	18 97	425 80	44 00	14 59	458 68	5 37	50 00	42 09	581 85	190	3 06
April	88 03	176 65	5 50	12 50	282 68	93 75	14 58	373 01	5 37	50 00	42 09	488 47	106	4 61
May	114 64	158 45	3 00	13 87	289 96	30 00	14 58	317 67	5 37	50 00	42 09	432 00	130	3 32
June	156 12	224 75	6 54	17 31	404 72	177 89	14 59	573 35	5 37	50 00	42 09	694 66	148	4 69
July	74 99	119 75	6 45	11 05	212 24	36 23	14 58	245 55	5 36	50 00	42 09	360 50	92	3 92
August	89 42	143 35	6 45	11 89	251 11	68 89	14 58	316 24	5 37	50 00	42 09	432 04	88	4 91
September	59 91	97 40	6 43	7 08	170 82	14 25	14 59	186 15	5 37	50 00	42 09	297 12	64	4 64
October	63 32	114 40	6 35	6 72	190 79	28 73	14 58	221 03	5 37	50 00	42 09	331 56	76	4 36
November	61 85	114 40	6 35	8 63	191 23	30 00	14 58	220 83	5 37	50 00	42 09	333 27	74	4 50
December	191 37	316 30	6 35	25 32	539 34	190 61	14 59	712 87	5 37	50 00	42 10	842 01	234	3 60
Totals and averages	$1,369 56	$2,104 65	$72 85	$160 31	$3,707 37	$859 60	$175 00	$4,508 81	$64 42	$600 00	$505 09	$5,911 48	1482	$3 99

* The figures in Column 6 include preparation of cuts and lithographic stones, and paper and presswork on insets.

† The figures in Column 11 include Secretary's trips to Chicago, etc., $94.45, and to Pittsburg, $31.21, and all other expenditures of the Association (such as stationery, postage, circulars, etc.), chargeable to the JOURNAL, and not embraced in any of the other columns. They do not include the cost of preparing reprints of papers.

‡ The figures in Column 13 include 4 cover pages in each number, and 24 pages in indexes to Vols. XIV and XV.

The cost of the Index to Engineering Literature, for 1895, was approximately as follows:

Compilation		$175 00	
Composition:			
Linotype	$115 63		
Making up	87 61		
	———	203 24	
Rearranging for December	$22 50		
	———	225 74	
List of periodicals indexed:			
Charge for type standing, 4 pages, say		7 00	
Paper, presswork and binding:			
11 months, 145 pages, say 9 forms, at	$21 75		
	———	195 75	
December, 110 pages, 7 forms, at	$21 75		
	———	152 25	$755 74

The use of the linotype machine has thus effected a reduction of about $170 in the annual cost of this department; but, by order of the Board of Managers, the publication of this index in the JOURNAL ceased with the December number of 1895.

By direction of the Board of Managers "the Contribution Box" and "the Library" were discontinued also.

The mailing lists of the JOURNAL, at the close of 1894 and 1895, compared as follows:

	1894.	1895.
Boston Society of Civil Engineers	353	390
Western Society of Engineers	337	401
Civil Engineers' Club of Cleveland	187	139
Engineers' Club of St. Louis	163	170
Civil Engineers' Society of St. Paul	34	32
Engineers' Club of Minneapolis	33	25
Engineers' Club of Kansas City	25	22
Montana Society of Civil Engineers	42	64
Technical Society of the Pacific Coast		168
Denver Society of Civil Engineers		28
Association of Engineers of Virginia		38
	1174	1477
Extra copies to members of the Board of Managers, five each	70	80
Advertisers	27	23
Exchanges	110	122
Subscribers	176	215
Complimentary copies	15	18
	1572	1935

Besides this, many copies have been sold and specimen copies sent out; and authors of papers have each received five copies of the JOURNALS containing them. Of the January number 2,200 copies were printed, and 2,400 of each of the others.

Vol. XIII (1894) contained 1,290 pages of printed matter, 86 cuts and 54 plates and full-page cuts.

The continued increase in the bulk of the JOURNAL rendered it advisable to divide the twelve numbers issued during each year into two volumes. Those for 1895 comprise Vols. XIV and XV, and contain, together, 1,482 pages of printed matter, 116 cuts and 66 plates and full-page cuts as follows:

	Papers.	Contribution Box.	Library.	Chairman's Report.	Pr'c'dings.	Index & Ads.	Total.	No. of cuts.	Plates & full-page cuts.
January . .	87	3	6	16	16	30	158	12	8
February . .	51	4	5		24	30	114	4	2
March . . .	133	4	3		25	21	186	19	2
April . . .	58	4	2		8	30	102	7	8
May . . .	82	0	2		10	32	126	0	1
June . . .	89		1		10	28	128	12	14
July	56				6	26	88	9	3
August . .	56				2	26	84	23	6
September .	28				4	28	60	6	1
October . .	32				10	30	72	13	0
November .	34				8	28	70	3	3
December .	86				12	126	224	8	18
	792	15	19	16	135	435	1412	116	66
Covers							48		
Index to Vol. XIV . . .				16					
" " " XV . . .				6			22		
Total							1482		

The number of pages issued in 1895 thus exceeds, by 192, or about 15 per cent., that of 1894 (Vol. XIII), which was the largest that had appeared up to that time; and the JOURNAL for December, 1895, with its 230 pages, is the largest that has been issued by the Association.

The following table exhibits a comparison, in several particulars, between the operations and condition of the years 1894 and 1895:

	1894.	1895.
Excess of liabilities over assets, December 31	$758 91	
" " assets over liabilities " "		$223 93
Number of Societies in Association " "	8	11
Number of names on mailing lists of Societies in Association " "	1,174	1,477
Number of subscribers " "	176	215
Annual receipts from subscribers, @ $3.00	$528 00	645 00
Number of advertisers	25	23
Annual receipts from advertisers	$850 00	679 84
Total pages in JOURNAL	1,290	1,482
" cost of "	$5,774 59	5,911 48
Cost per page	$4 48	3 99
Average number of copies issued monthly	1,958	2,383
Number of small cuts	86	116
" " plates and full-page cuts	54	66
Cost of illustrations	$651 60	859 60
" " index to current literature, approximate	$926 00	755 74

The JOURNAL has throughout the year enjoyed the advantage of second-class or "pound rates" of postage (1 cent per pound).

Of the 50 copies of the bound volume of the "Descriptive Index," covering the years 1884–1891, accepted from Mr. John W. Weston, the former Secretary of the Association, in settlement of a balance amounting to $72.02, sixteen copies have been sold, realizing $37.50.

During the year, the Technical Society of the Pacific Coast, numbering 168 members, has become a member of the Association. The union between the ten societies now forming the Association is thus made co-extensive, in longitude, with that between the States of the Union, reaching from the Atlantic to the Pacific.

In March I visited Cleveland, Indianapolis, Louisville, Cincinnati, and Pittsburg, on behalf of the Association.

At Cleveland I attended, by invitation, the banquet of the Civil Engineers' Club of that city, one of the four original societies forming the Association, and received many hearty assurances of the loyalty of the Club to the organization.

In Chicago I attended, with you, also by invitation, a meeting of officers and prominent members of the Western Society of Engineers, held for the purpose of considering those matters which had led certain members of that society to desire its secession from the Association.

As you will remember, we were assured by those present at the meeting, that all the matters in dispute had been satisfactorily adjusted, and that the question of secession was thereby rendered a dead issue.

On the 24th of September last, the Society, by letter ballot, reversed its action of 1894, and decided, by a vote of 179 to 87, to withdraw from the Association.

In Indianapolis, Louisville, Cincinnati and Pittsburg, I met with members of the societies in those cities and laid before them the advantages of membership in the Association.

In April, I again visited Pittsburg and addressed the Society there upon the same subject.

Very respectfully yours,

JOHN C. TRAUTWINE, JR.,

Secretary.

ASSOCIATION

OF

ENGINEERING SOCIETIES.

Organized 1881.

VOL. XVI. | FEBRUARY, 1896. | NO. 2.

ENGINEERS—CONSULTING, INSPECTING, CONTRACTING.

Their Relationship to each other and to their Clients.

By GEO. W. DICKIE, MEMBER OF THE TECHNICAL SOCIETY OF THE PACIFIC COAST.

[Read before the Society, June 2, 1895.*]

IN opening up the questions that naturally gather around the title of this topical subject, I do not expect to be able even in the most limited sense to do so exhaustively with regard to any one of the divisions under which I desire to arrange my remarks.

My object in presenting this subject now, is to bring out, if possible, a general expression from the members of this Society, of how these questions have affected them in their practice.

We have members whose special line of work comes under some one of the divisions I have made, and who must have very decided opinions in regard to the duties and obligations of engineers whose work would be classed under some other division than that in which they themselves are placed.

I am fully alive to the danger incurred in treating this subject and I shall be careful to avoid any expression that might tend to wound any of those whose friendship I hold in the highest esteem. So, if I do say anything that hurts, let it be understood that the reference is not to the practice of any local engineer, but to some bad practices I have read about as being done in the East and in Europe.

* Manuscript received January 15, 1896.—*Secretary, Ass'n of Eng. Socs.*

Naturally, and by preference, due to my limited knowledge, my remarks will have special reference to mechanical engineering. Other members, skilled in the practices of the civil branch of our profession, will, I trust, take up these questions, and tell us how things are done in the various relationships in which civil engineers stand to each other and to their clients.

As I will confine my remarks to what I have observed in connection with my own experience, my task will be an easier one than if I had to look up the statements of others and find authority for accepting them myself or for presenting them to you as truth.

I have placed the consulting engineer in the first division of this subject, because I think the position he occupies, or should occupy, is of the first importance. Great interests, affecting not only his clients, but, it may be, the welfare of a whole community, often depend upon his judgment.

In the mechanical branch of the profession there are not many consulting engineers that meet my idea of the requirements of that position. Standing, as he does, as a judge between the individual or the corporation who provides the means to carry out an enterprise, and the other individual or corporation, who, for the money expended, is to produce the plant required for the purposes of such enterprises, he must, in order to be successful, possess complete and accurate knowledge not only of the things required, but also of the capacity and ability of the men that are to produce these things.

A consulting engineer, if he has the full confidence of his client, gives advice, not only as to the materials which his client needs for the purpose he has in view, but also as to whom he should employ to produce these things. This is the most difficult duty required of the consulting engineer, and the one that gives him most trouble; for, amongst all the contracting engineers that are desirous of having his client for a customer, only one will approve of his advice; all the others will accuse him of ignorance, and some of them, may be, of something else. It is, therefore, of the first importance that the consulting engineer should possess a most complete and accurate knowledge of the latest and best practice in regard to all the matters on which he is consulted.

Some engineers are honest and will not pretend to give advice unless they are conscious of their ability to give their client the very best thing possible for the purpose in view. Others are simply after the consulting fee, and run around amongst the manufacturing engineers, getting this one's idea and that one's idea, and out of these patching up a sort of specification that the client accepts as his engineer's requirements for the work on hand, while, if he had gone direct to any one of the sources where his engineer got his information, he would have got a specification that at least one man could give a fair bid on.

This kind of consulting engineer has of late fallen into a trick of protecting himself by specifying that the work he is supposed to have planned out and carefully described, is to perform certain functions under certain conditions, and with a certain minimum economy, and the hapless contractor is required to guarantee that the result will be at least equal to that specified.

If the consulting engineer is competent to do what he has undertaken, he will also have confidence enough in his own work to be able to assure his employer that the result expected will be obtained without placing a third party in a false position.

In other words, why should the engineer's client ask a contractor to insure him against any mistake he may have made in employing the wrong man as a consulting engineer?

It appears to me that, as things are now, there is a grand opportunity for an Engineering Insurance Company which would employ the best talent in each line of work, and to which capitalists would submit plans and specifications prepared by their consulting engineer; and, should the Insurance Company's experts approve the plans, they would be accepted as a reasonable risk and the result insured in a sum equal to the cost thereof, at a reasonable premium.

This practice on the part of consulting engineers, of requiring a contractor to guarantee that their design will accomplish all that they have promised their client, has become so much a matter of course that we are never surprised even at the most childish expression of it in a specification.

Looking over a contract and specifications for barges, drawn up by the consulting engineer for a Russian company, the other day, I found the following:

After giving plans and dimensions for the barges and specifying the weight of material, the engineer requires the contractor to guarantee that the said barges will carry 500 tons on 3 feet 6 inches of fresh water.

Now, to his employers, this engineer appears to be protecting their interests, but if he had specified something to be 10 feet long, and then required the contractor to guarantee that it would be 120 inches long, they would have thought him rather too childish for a consulting engineer.

There are, however, some notable exceptions to this type of consulting engineer. Some two weeks ago I had to estimate the cost of large pumping works designed by Mr. E. D. Leavitt, of Cambridgeport, Mass. The drawings were very complete in every detail, clearly figured out and so indexed for reference that the work of estimating was a pleasure. The specification was brief, and stated distinctly the point

of beginning and the point of ending of the proposed work, and what was meant by the words used in the drawings. The contractor was held responsible for the quality of material used and of work done thereon. But he was not asked to guarantee that Mr. Leavitt's design of engine would successfully accomplish the results that he had promised. In fact, the economic result expected of this design was a matter that lay entirely between the water board of the city and their consulting engineer, and with which the contractor had nothing to do. In this respect Mr. Leavitt sets a good example to the consulting engineers of the country, and his reputation is largely due to the fact that nothing leaves his office until it is thoroughly worked out, and no outsider is asked to take the responsibility of any design bearing the name of E. D. Leavitt.

This is the position I would like to see all consulting engineers take in regard to their work. It would add to the dignity of the profession. The client would be more careful as to whom he employed as engineer advisor. The contractors would not be tempted into promising impossibilities, and in the end resorting to trickery to hoodwink an incompetent engineer into believing that the impossible had been realized, at least in this one case.

If my friend, the consulting engineer, will pardon my boldness, I will say to him, be sure of your ability and experience to plan the very best thing to fulfill the conditions of the problem you are to solve. Then go ahead, but don't ask a contractor to guarantee that you have not made a mistake.

The inspecting engineer may be either the consulting engineer himself, or his representative, or he may be an independent engineer employed directly by the principal party to the contract.

His duties are the same in either case, and consist in seeing that all the obligations under which the contract and specification places the contractor are faithfully fulfilled.

The inspecting engineer should have an accurate knowledge of all the detail of the work he is to inspect; should know the conditions under which each part of the work operates when performing the functions for which it was designed; besides, he should have a good knowledge of men and of their weaknesses, and above all he should have a good temper and a tender heart, for while he is expected to do justice, he should also love mercy.

Much of the trouble that often occurs between inspecting engineers and contractors is caused by improperly written specifications.

I sometimes think that specifications are written for the express purpose of preventing the contractor from building the work specified without evading the provisions of the specifications or coaxing the inspector to read them through his spectacles.

Why should a specification say that the material used should be the very best possible of its kind, when, of any two pieces of material taken at random, one will be better than the other, which would mean, by the language of the specification, that one shall be taken and the other shall be left. Why should castings be specified to be free from all defects, shrinkages, scales or scabs, when such a thing is the exception and not the rule. Why specify workmanship to be perfect, when there is no such thing as perfect workmanship.

I am in the habit of writing specifications in the following way: The materials used shall be reasonably good, and fit for the purpose for which they are to be used. Castings are to be good and sound, and reasonably free from defects that would affect their strength or sightliness. The workmanship is to be good, and of the character required for each part of the work. This is usually scratched out as not likely to produce the best result, and the usual absolute perfection is inserted, and coupled with another requirement, that the whole work must be done to the entire satisfaction of the inspecting engineer. This word, satisfaction, is a mistake, for an engineer may not be, and very often is not satisfied with work, when done according to the specifications and contract.

I once had to do work under an inspecting engineer, who claimed, that the clause, requiring that the work must be done to his entire satisfaction, meant that the work should be done over and over again until he was entirely satisfied; and when I required him to state what would satisfy him, he claimed that the specifications did not require him to instruct us what to do, but simply to say whether he was satisfied with it when done. He claimed, in effect, that, whatever his whim, caprice or notion required in order to be satisfied, we must meet the demand, for we had contracted to do this work to his satisfaction.

My idea of an inspecting engineer is, that he should be a consulting engineer to the contractor. It is unfortunate when inspectors are suspicious of the contractor, and the contractor is afraid to show to the inspector any little defect that he discovers. There should be mutual trust and confidence between them. A contractor should never ask an inspector to look at anything that he himself, if inspector, would condemn; but, if he has any work on hand wherein there has been developed some slight imperfection in material, or where some workman has made a mistake, so that the finished work will not be strictly according to the specifications, but quite good enough for the purpose for which it is to be used, he should be able to show it all to the inspector, confident that no advantage will be taken of his honesty. How often a contractor is driven, through fear of losing good property, owing to lack of confidence, to run the risk of an inspector failing to find out the defect in material, or

error in workmanship. Inspectors expect this course to be taken, and are slow to admit the possibility of an honest contractor. I have often asked inspectors to come and look at work that was not just as it ought to be, and yet altogether too good to condemn, and found that the fact of my pointing out the defect was enough to condemn the work.

One inspector used to tell me that he could not conceive of my calling his attention to work that I thought was good enough, and that my coming to him was, to his mind, an evidence that I did not want the work to pass, but that I wanted his assistance to condemn it. My experience is, that to call an inspector's attention to a fault, however slight, is to have the work condemned.

This is not the result of want of knowledge on the part of inspecting engineers, but is due rather to a misunderstanding between the parties in interest as to their relationship to each other. There should be full confidence between contractors and inspectors. Any defect, however slight, should be accepted, if at all, with the full knowledge of the inspector. The inspector should take into account all the difficulties that beset the contractor. Some inspectors appear to think that they are expected to earn their remuneration by making the work more costly to the contractor.

An old engine builder, on the water front here, said that he made a contract to build a set of machinery for a heavy tow-boat, and "I was dead sure," said he, "at the beginning, to clear $5,000 on the job, but they hired a man to prevent me from making that $5,000, and he was a splendid success; for, before the job was finished, the sheriff had my shop, and even he could not satisfy the inspector." Inspectors are not all of this type, however, and the better fitted they are for the responsible position they hold, the more pleasant the relationship will be between them and the contractor.

During the past six years or so I have had much to do with Government inspectors, and I had often been told how hard it was to get along with them; that nothing would satisfy their critical methods of inspection; and yet I have found the Government inspector not only a gentleman in the highest and best sense of the term, but also a great help in meeting the requirements of the contract. I have always felt perfecty safe in giving them full information in regard to all material and work, and have always found them ready to take a reasonable and practical view of the case. I am happy to be able to give this testimony and am proud of the professional staff that have represented the Government from time to time at our works.

In regard to the contracting engineer, I cannot speak so freely as I have done of the others. I belong to that class myself, and it is very difficult to see ourselves as others see us. Yet we are conscious of great

room for improvement in our methods of doing work, as well as in our relationship to the other two classes of engineers and to our patrons. Keen business competition makes the battle a hard one for the honest contracting engineer. Sometimes it would appear that the old road that leads to success, that of honesty and skill, combined with great pride in the character of the work turned out by his establishment, is no longer open to the contracting engineer. He must now aim at the greatest apparent result for the least cost. Each one tries to promise something more than his competitor, and the one that tells the best story, rather than the one who has the best skill, is apt to be entrusted with the work for which they are competing.

Change now seems to be written on every product of engineering skill. Work involving much thought and experience in its production is discarded for something else before it has had time to earn a reputation for the engineer that produced it.

In our time, business reputation depends not so much on what we have done as on what we propose to do next. Yet I am not ready to accept this condition as either permanent or true. And I would say to my brother engineers that I am more and more convinced that there is no near cut to engineering reputation, however much the rapid changes now going on in engineering practice may tend to deceive us into such belief. To reach a permanent reputation for great skill in any one line of engineering, our life must go into it, trudging along the old well-beaten track of honest, steady and intelligent effort. The value of what we produce should be measured, not by what we got out of it in the shape of profit or present notoriety, but by what we put into it of honest skill and ripe experience.

In the efforts now being made to draw trade to our State, let us avoid the miserable scramble after the cheap and temporary, for no lasting prosperity or individual reputation can be sustained on such a foundation. Let our aim be to produce the very best within the compass of our skill and then produce that thing, but no other, as cheap as possible.

Between consulting and contracting engineers there is not that desire for mutual helpfulness that there ought to be. The contractor is often ambitious to be the consulting engineer, and, in some cases where his experience gives him special fitness for this position, it is quite right that he should be so, and no antagonism should result from such practice. In certain branches of engineering, the contractor must maintain a large staff of skilled engineers at his works, and he is thus in a position to bring to bear on the problems an accumulation of skill and experience that no consulting engineer could match; but a contractor should be in such a position before he undertakes to come in between the consulting engineer and his client.

The position of the consulting engineer in California will, I think, improve. Capital is being more and more invested through corporations, and the consulting engineer must find his proper place as the technical advisor of such corporations.

We need a better understanding between the various branches of our profession. We must have a high standard set up for engineers to reach before being considered competent to give advice in regard to great engineering enterprises, or to inspect the work in progress. Nor should that standard be lower for the contracting engineer, who guides the skill which produces the results promised by the consulting engineer and satisfies the keen eye of the inspecting engineer who represents the interests of those who provide the needful.

DISCUSSION.

Mr. Richards.—Mr. Dickie has found no reason to impute dishonesty to a single individual, but attaches the highest integrity to the profession. Our romancers, in their novels, make villains of everybody but the engineer. There is no other profession that stands upon so high a plane morally and ethically.

Mr. von Geldern.—I beg to call Mr. Richard's attention to Charles Dickens' Pecksniff who may be counted among our fraternity.

Mr. Randell Hunt.—Mr. Dickie raises the question whether the Consulting Engineer should not maintain a position different from that which he now occupies, and whether corporations and others seeking the advice of engineers should not ask the advice of a Consulting Engineer where they now depend upon an engineer in their own employ.

I think there will be no advancement of engineering as a profession until the engineer ceases to be the contractor; until he occupies an entirely separate and distinct position. At present the drift is in the other direction. The engineer is becoming the contractor.

There have been issued recently, in this city, two sets of specifications for structural work. In one of them the specifications call for plans for the structure. In other words, the specialist's advice is sought. The engineer who drew up the plans is evidently not a specialist. I maintain that the proper position for a chief engineer is: To go out into the field of engineers and to employ a specialist to draw up the specifications for the structure he wishes to build. Instead of that he follows the usual rule, and specifies very broadly that he requires the structure to fulfill certain conditions, and wishes plans, etc., submitted. He is seeking, in other words, the advice of a dozen specialists for nothing, and he is going to get it, and perhaps more.

Looking at it entirely from his standpoint and the interest of the

corporation in which he is employed, he is probably doing his duty. But is he not lowering the status of the engineering profession? Is he not putting the engineer into the place of the contractor?

I am at present a contracting engineer. I am one of the unfortunates who are making plans on this proposition. I am giving a great deal of time merely for a chance to build this or that structure. I do not complain of the opportunity. I am seeking it in every direction in these hard times. But is it a proper and legitimate position in which to place the profession? I think not.

The other set of specifications is almost identical. It is seeking technical advice *for nothing*. The public has to pay in the end for all the plans that are made.

I maintain that engineers, if they are going to make a profession of engineering, must put themselves on a different basis. I see no reason why corporations should seek plans and original designs for nothing by thus asking for bids in competition, any more than a person should do so in building a house. The architect, in the building of a house, occupies identically the same position as the engineer occupies, or ought to occupy in his work. The architect is entirely independent of the contractor in every way.

Now, there is another way of looking at this. By going to a single specialist and having him draw up plans and designs, would the profession advance as much as it has done under the present system? Is it not a fact that the financial part of the proposition—the fact that the contractor becomes the engineer—is one of the chief incentives to an original design? Is not that the reason, or is it not one of the chief reasons why engineering, in almost all lines, has jumped forward with such bounds? The capitalist, for instance, says to his engineer: "That will not do; it is entirely too expensive." Such a remark will immediately make the engineer seek to construct on cheaper lines, and in that way he will develop a proper theory, one which can be applied at the minimum expense. That has been particularly the case in regard to civilengineering structures in this country.

I believe there is no country that has made greater advancements or has shown greater originality in structural work, than America, and the chief incentive to a correct design has been the financial problem.

Looking at it from this point of view you may say that the position I first took is entirely wrong. But I do not see it so. I think the engineer has a duty to himself to perform, and that duty will be best performed when he occupies a purely professional position.

There are certain points in Mr. Dickie's paper that strike me as though he were writing rather from the point of view of the contractor with reference to engineers, and from his experience with them in that

way. I have occupied the position of engineer, and that of contractor, and sometimes the dual position of both contractor and engineer; but I have found no dishonesty among engineers in the usual interpretation of the term. I have, however, found something of a disposition to saddle upon others the ignorance of the engineer. Mr. Dickie has, to a certain extent, brought out this point in his paper, by remarking that an engineer, after specifying various things, also requires that the work, or the structure, shall be perfect. That is always, in my opinion, a confession on the part of the man who draws up the specifications, that he is not quite sure of himself; that he does not know whether he has met the proposition quite as it should have been met. I regard this as one of the principal faults engineers should strive to correct. If an engineer is called upon to draw up a set of specifications not in the direct line of his specialty, let him do what he should do—frankly say that he wishes to call in special advice in the matter. There is hardly an engineer to-day, employed by a large corporation, who dares to do it. The employer will say, "What do I hire you for? If you do not understand the problem we will hire someone else." No man can acquire all the technical knowledge in the world. It is an advantage to have specialists, and we engineers understand that, perhaps, better than others. When an engineer is called upon to design something a little out of his line, he should frankly call in advice upon the subject, instead of obtaining it, as usual now, from others for nothing.

Prof. Marx.—What Mr. Hunt has said suggests to me that a little might be said on the other side.

It seems to me, for instance, that the calling for plans from several large contractors carries with it a certain advantage which will inure to the benefit of the corporation in whose employ the engineer may happen to be. The engineer should see in what way their interests are best served. It seems to me the middle way might be best for all.

Mr. Hunt suggests that an engineer may not be capable of drawing up all the plans for a particular piece of work. In this case a specialist might be called in to aid him in the outlines, but not necessarily in every detail. When bids are made from the plans submitted by the contractor, it is very often possible that practical modifications of the design, which will fulfill the object of construction, may be of great economic value, and the importance of such modifications cannot properly be overlooked by the engineer. Or it may be that the particular firm that has bid for the contract is in position, owing to certain local conditions, to use up a certain amount of material which it has on hand, if allowed to make certain changes, and those changes might not affect materially the use and durability of the structure.

I think, perhaps, a combination of the two methods might bring

about a more satisfactory result than is attained by holding the bidding firm strictly to the plan of the head engineer. Suppose he had drawn up certain plans. Is it desirable to bid on those plans alone? Would it not be wiser, and just as fair, to allow the bidders to make certain changes in the plans, if by so doing the structure could be as well built, and at the same time be a more economical structure for the corporation?

Mr. Hunt.—Does not this make it simply a matter of competition between engineers?

Prof. Marx.—Well, we will leave the decision to the consulting engineer, who has been employed by the chief engineer; he not being able to draw up the plans of the building, or to change the plans submitted.

Mr. Hunt.—I do not think there should be competition among professional men. I do not see any more reason for seeking competition among professional engineers in the matter of a design, in the ordinary course of work, than for seeking a competitive legal opinion on a matter; it would be identically the same proposition. If we are going to make a profession of engineering we must put a man upon a professional elevation, and seek his opinion, just as we would seek a medical or a legal opinion. We may not in this way get the best advice, any more than we can always be sure to get a correct interpretation of a mooted law point from one attorney. We would be very apt to get a better one if we made it a matter of competition among eight or ten attorneys, Undoubtedly a man is serving the interests of his corporation if he can. get the most for the least, but I do not view it in that manner.

Prof. Marx.—I did not take quite that extreme view. The plans are submitted to the approval of the consulting engineer. I think that in the large bridge structures on the Danube it was left to the bidding firms to submit bids on their own designs, and then the designs were submitted to the decision of a commission.

Mr. Hunt.—Undoubtedly that is an incentive to the production of numerous beautiful and original designs.

A Member.—Hawkesbury bridge was the result of the competition of the world. It was built for about one half what it would have cost without this competition.

What experience I have had has been with contracting firms in structural work. In submitting bids, the company I have been connected with prefers to prepare its own plans, at its own expense, rather than submit a bid on the plans of a consulting engineer. In bridge work especially, railroad companies prefer their own plans, as their workmen are familiar with their methods and details, and they can do their work much cheaper than if they were working under a new set of details.

It seems to me that the middle course would be the proper one in such cases, and that the consulting engineer could give a decision as to form and general dimensions, leaving it to the contracting firm to submit the details to be approved by the head engineer.

Mr. Hunt.—I have been talking directly against my own stand as a contractor. What I have said to-night is by no means my business opinion. It is an opinion that I am giving freely and frankly as an engineer. I am a contracting bridge engineer, and the gentleman has expressed my position in the matter plainly, and I do exactly what he says. It is for this simple reason that I prefer to submit my own designs, and I feel that I have a better chance in competition by doing so. But I must say that I do not think it a fair position to either party. In the first place, I do not believe in making a consulting engineer occupy the position that has been spoken of here. I believe consulting engineers should occupy purely the professional position of giving advice, making plans and specifications, and being paid for them. If a corporation wishes a special structure it should secure special professional advice.

Mr. Richards.—The position of the consulting engineer is a matter of evolution. It will be a quarter of a century before the consulting engineer in the United States will be in the position of the consulting engineer in Europe. His method and treatment will prove what I say. In one case the consulting engineer submits his views, and he is not supposed to know whether they are adopted or shown to anybody else. That is none of his business. That is the true consulting engineer, in the sense in which the term is used in the old country. In other cases his opinion is submitted to the principals of the works; and he appears before them, argues the points and shows wherein his method is correct.

The objection, on the part of employers, to calling in consulting engineers, exists in some cases, but not in all. A short time ago I was called upon to give advice in a very important case. It involved a matter of three million dollars. I spoke to the Commissioners about calling in additional advice and they said, "Certainly, call in some one else, or more than one, if you think best."

There are all kinds of conditions to be met. One cannot define just what the duties should be.

The first consulting engineer in the United States was Mr. Arthur, of New York. He opened his office about 1870. He was an old Scotchman. He was soon followed by Charles Copeland, who died a few months ago.

On this coast the idea is new. It has been forced upon the people. No one wants the consulting engineer, but he has to be employed.

Contractors, in most cases, I am happy to say, submit plans honestly and fairly. They do not always do so, nor do they always estimate on

a fair basis. Sometimes they form collusions—I have heard of such things; and the consulting engineer must be called in.

As I said before, it is a work of evolution. The position of the consulting engineer is entirely different from that of the civil or mechanical engineer. In static engineering one can get at the material, make computations, and devise plans very nearly alike. In machinery it is different. There is no standard at all for these things, they are not computable. The consulting engineer, in many of his operations, proceeds without any aid from books or personal experience. He must be about fifty years of age before he knows very much, and he then discovers that his knowledge, in many important details, is limited.

Mr. Byron Jackson.—I have had to do the consulting engineer's work from the standpoint of the contractor; that is, I have acted as both.

I think that the consulting engineer, as well as the contractor, should be made to compete.

In my opinion contractors should be made responsible for putting in the best material. I have to use that particular clause in my line of work, and I have found it necessary to say, "the best of its kind." It is a very simple matter to get over, and generally answers the purpose. We can spin the specifications out at length; but we are generally compelled to cut them short by saying that the material shall be of such a character. Of course, specifications should be explicit.

I believe that contractors, as a rule, can be depended upon as well as consulting engineers. They are compelled to act in good faith, for, if they do not, they will get no more contracts. Our people are perfectly willing to employ a consulting engineer, if such employment is not too expensive. I think that in many instances specialists should be called in to give assistance.

Mr. Bestor.—Mr. Hunt urged that the engineer, like the architect, should occupy a more independent position. There is just the same trouble with architects as with engineers and contractors. They are taking work for which they alone design the plans; except in the larger and better works, where they have the privilege of bringing in experts. Take electric lighting, for instance—where the expert is called in and is paid for his services. I do not see why the superintending engineer or the consulting engineer should not do the same thing.

It seems to me this question is open to much argument, and can be much varied. The standing of the consulting engineer will be defined by an evolutionary process, as Mr. Richards says. It will take time to improve it.

Mr. Dickie.—I do not know that I am under obligations to refer

to anything that has been said about this paper, because I simply undertook to open the discussion. I am not responsible for its outcome.

The main point that I wanted to bring out in the paper is that the consulting engineer should be sure of his own position, and when he specifies certain things, he should hold himself responsible for the result. The principal difficulty in the relationship between contracting and consulting engineers lies in this responsibility. It is not the fault, perhaps, of the consulting engineer, but that of his client. The party who is going to invest a large amount of money in some engineering enterprise, wants a guarantee that by the use of a certain amount of capital his project will prove all that his engineer proposes it shall. There is where the trouble lies. Those who invest should not ask a third party to guarantee their own design. If they employ a consulting engineer they ought to be satisfied with their choice and look to him for the result.

I think this trouble could be obviated if the consulting engineers would take a firm stand in regard to it. Let them be upon their dignity and be prepared to maintain hat this responsibility rests with them.

Yesterday we were testing the pumping engine for the Spring Valley Water Works. We had nothing to do with designing the engine. The plans were made and prepared by their own engineers, and yet the contractors were required to give a guarantee that the pump should perform a certain duty. The contractor is perfectly powerless; he cannot make it any better or worse than it is. He should try to make the machinery as perfectly as human skill can make it, and there his responsibility should end. When a contractor prepares and follows his own designs, then, of course, he is responsible for what he constructs. When the consulting engineer prepares plans and specifications, and these plans are sent out and bids are made upon them, that engineer, and no one else, should be responsible for the results. This particular point I want to call your attention to in regard to consulting engineers.

Referring to inspecting engineers I wished to bring out this point, that there should be a better understanding between inspecting and contracting engineers. They ought to be friends instead of being suspicious of each other. There should be no such thing as cringing on the part of the contractor toward an inspector. There should be no striving to hide things, which there is no reason to hide all. Especially in machinery, no work is entirely free from defects, but these may not prevent it from answering fully all its purposes. If work were perfect there would be no need of inspection.

In regard to contractors, I think they ought to take a higher stand

than they do. Ethics should control them in their business. We can all afford to tell the truth. Yet, what may be true in the morning may be a lie before night. I have often told a man in the morning that a thing was so and so, and by evening affairs would be in such a shape that he would tell me it was untrue, and yet I had had no intention of telling a falsehood. What I have said was perfectly true when I said it.

Inspectors ought to understand and sympathize with contractors who do their best. When they do, we shall have better work and better machines.

TRIANGULATION PREPARATORY TO ALIGNMENT OF A TUNNEL.

By Wm. W. Redfield, Member Engineers' Club of Minneapolis, Minn.

[Read before the Club, March 2, 1896.*]

In the spring of 1884, the Water Board of Minneapolis, Minn., decided to sink a shaft in the northeast corner of Pumping Station No. 2, commonly known as "The East Side Pumping Station," and situated on Hennepin Island in the Mississippi River; also to sink another shaft on the eastern shore of the Mississippi River, on Third Avenue Southeast, about twenty feet east of the east line of Main Street; and also to connect said shafts at bottom, by a tunnel; all for the purpose of conveying two 30-inch water pipes across the east channel of the Mississippi River. As every one familiar with the geology of Minneapolis well knows, the shafts successively pass through earth, limestone and sand-rock of a yellowish-white color, the latter easily worked with the pick, and very favorable for tunnel driving. The lower surface of the limestone ledge being nearly level, forms an excellent roof for a tunnel. In fact, the numerous tunnels for the tail-races of the various mills are nearly all driven immediately under this ledge. It was decided to made the shafts circular in shape and 10 feet in diameter; and the connecting tunnel, rectangular in cross-section and 8 feet 6 inches wide in clear, lined on both sides with a rubble wall 16 inches in thickness, and 5 feet 4 inches clear height, and floored with concrete 2 inches thick. The natural way in this work would have been to sink the two shafts to the depth desired, and with two points at one shaft in line with two similar points at the other shaft, to transfer each pair of points to bottom of their respective shafts by careful plumb lines, from which the tunnel alignment would be made. This would have been the *only* way possible at this tunnel if it had not been for the fact that six other tunnels were to be crossed at nearly right angles, their general elevation of water surface being fortunately below the level of the bottom of the tunnel proposed. Three of these tunnels carried tail water from saw-mills; another one was an abandoned tail race, as was also the old Government tunnel; and a sixth one was the tail-race of the Island Power Company, quite deep, having recently been lowered. Of these, the Martin and Todd saw-mill tail-race crossed nearest the center of proposed tunnel, and as it was desirable to let shafts and tunnel separately by contract, and in order to save time, it was decided to commence driving the tunnel a little before the shafts were

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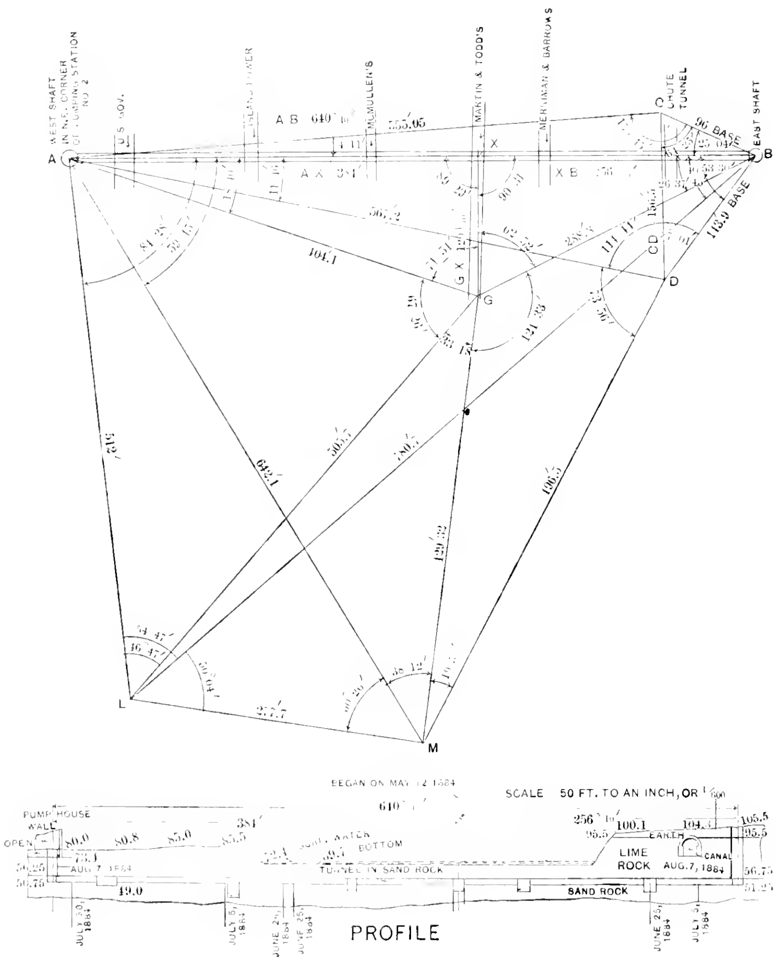
WEST SHAFT IN N.E. CORNER OF PUMPING STATION NO. 2
U. S. GOV.
McMULLEN'S
MARTIN & TODD'S
MERRIMAN & BARROWS
CHUTE TUNNEL
EAST SHAFT
A
B
C
D
G
X
L
M
AB 640
555.05
96 BASE
113.9 BASE
404.1
567.2
513
642.1
505.5
480.5
496.5
277.7
BEGAN ON MAY 12 1884
SCALE 50 FT. TO AN INCH, OR 1/600
PUMP HOUSE
WALL
OPEN
80.0
80.8
85.0
85.5
384
256
100.1
104.3
105.5
95.5
EARTH
LIME ROCK
CANAL
AUG. 7, 1884
TUNNEL IN SAND ROCK
SAND ROCK
BOTTOM
49.0
56.25
56.75
51.25
JULY 30, 1884
JULY 5, 1884
JUNE 25, 1884
JULY 5, 1884
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begun. Accordingly the Martin and Todd tunnel was selected as a means of access, and the tunnel proposed was to be driven simultaneously east and west from the saw-mill tunnel towards each shaft; these shafts did not reach the bottom of the rock for some days after the tunnel contractors reached and removed the sand rock below limestone at the bottom of each shaft. The task of providing alignment for the above, falling upon the author, he devised the system of triangulation as explained below, reference being had by letter or otherwise to the accompanying diagram and profile.

Points *A* and *B*, or centers of shafts, being located, two points, *C* and *D*, were established, and base-lines *BC* and *BD* were carefully measured; these being very short (96 and 143.9 feet respectively), *two* were chosen, as a check on each other; and it being at that time difficult to find any longer ones. Angles were observed as follows: *CBA*, *ABD*, *CAB*, *BAD*, *ADB*, *CDB*, *ACB*, *DCB*. From these elements *AB* was computed by two solutions from triangles *ACB* and *ADB*; *CD*, *AC* and *AD* were also calculated. This established the length of proposed tunnel to be 640.8 feet.

Next, to facilitate the entrance of a line up the Martin and Todd tunnel, a point *G* was placed at mouth of said tunnel in such position as to see therefrom up the tunnel. Auxiliary points were also placed at *L* on Hennepin Island, and at *M* on the east bank, both some four hundred feet down stream. The following angles were then taken: At *A*: *BAG*, *BAM*, *BAL*. At *B*: *ABG*, *ABL*. At *G*: *AGB*, *BGM*, *MGL*, *LGA*. At *L*: *ALG*, *ALB*, *BLM*. At *M*: *DMG*, *GMA*, *AML*. From these various angles and the proper triangles the sides *AG*, *BG*—*AL*, *GL*, *BL*—*AM*, *GM*, *DM*, *LM* were computed and the values found as indicated on diagram. This necessary preliminary work was prepared in the office beforehand, after doing the field work. Then on Sunday, May 4, 1884, when the mills were shut down, an indefinite line was run from *G* towards *X* and the angles *AGX* and *BGX* measured. Then, during the week following, from the angles *BAG*, *AGX*, *ABG*, *BGX*, and the sides *AG* and *BG* were computed the sides *AX*, *BX*, and *GX* (two solutions being obtained for the latter from the two triangles *AGX* and *BGX*). *GX* was the distance required to proceed up the saw-mill tunnel before beginning the work; the angles *AXG* and *BXG* (together necessary to be 180°) gave the proper angularity to turn at *X* from line *GX*, after measuring *GX*. *XA* gave total distance to proceed westward and *XB* total distance to proceed eastward to reach each shaft. The second set of calculations having been finished, on Sunday, May 11, 1884, the transit was again placed at *G*, and the angle *AGX* turned off, sighting towards *X*; the calculated distance *GX*, or 129.4 feet was measured

carefully on said line to point X, which point was thus established. Then the transit was placed at X and the angles AXG and BXG successively turned off, thus enabling a point on a line of proposed work to be placed both east and west. Next morning, Monday, May 12, 1884, work was commenced and diligently prosecuted to completion. The shafts were begun somewhat later, and finished to bottom of rock; the east one on or about August 7, 1884; the west one somewhat later, and the tunnel reaching both ends, as stated before, some days before August 7, 1884. The tunnel and shafts carry at present one boiler-iron pipe 30 inches in diameter in tunnel and a cast-iron pipe 30 inches in diameter in shafts, and placed on the south side of tunnel and shafts, leaving room for an additional one on the north side, whenever required. The accompanying diagram and profile give a few statements showing rate of progress and datum heights. At present date the pipe and tunnel and shafts have not ceased to give satisfaction. It might be of interest to state here that the pipe in tunnel rests on rollers at a suitable distance apart, bearing on iron plates, and near the middle of tunnel the pipe is provided with a sliding joint, like a stuffing-box, to take up any longitudinal expansion or contraction. The pipe at top of each shaft reduces to a 24-inch cast-iron pipe. The water comes from a computed 10,000,000-gallon pump, but ordinary daily work runs from 4,000,000 to 7,000,000 gallons.

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THE STANDING OF ENGINEERING AMONG THE PROFESSIONS.

ADDRESS OF J. S. KEERL, RETIRING PRESIDENT OF THE MONTANA SOCIETY OF CIVIL ENGINEERS.

[Read before the Society at Helena, Montana, January 11, 1896.*]

IN the past three decades, the very liberal education afforded by our public schools, and other institutions of learning, has received a full endorsement through the achievements of the present generation; not alone throughout the commercial world, considered generally, but more especially among those whose professions are based upon the applied sciences and upon their varied application to the practical questions of life and business.

Within this relatively short period, all the sciences and arts, and the collateral professions, have made herculean strides, not only in their own special advancement, but collectively, in advancing the progress of civilization, and in a much greater ratio then had ever before been achieved, in any quarter of a century, in the world's history.

The legal and medical professions have accomplished grand results. The opinions handed down by many eminent and patriotic Judges, and the learned arguments of Attorneys, take their place in the general advancement of mankind. The names of Pasteur, Koch, and others, of the medical profession, are now household words, and monuments in

* Manuscript received March 14, 1896.—*Secretary, Ass'n of Eng. Socs.*

themselves, by reason of their great discoveries. The ambition to understand life in its complex and varied conditions, when actuated by the desire to relieve suffering humanity, is surely one of the most worthy and honorable that can ever stimulate the genius of man.

These noble professions, the legal and the medical, are the two oldest, and the most fully recognized and appreciated by the public at large. Their antiquity, as well as their accomplishments and assertiveness, have won for them their well earned recognition and their fitting emoluments.

There is another calling, a profession not nearly so old, in fact an infant in view of the antiquity which surrounds the history of those above mentioned; and yet during its short existence, it has made such phenomenal strides, that, if judged from what it has accomplished, one would expect to find it prematurely gray. A profession which many savants have pronounced the only one which does not live by the contentions, miseries, and distresses of humanity, but alone deals with endeavors to advance mankind to the enjoyment of a higher civilization, by subduing, diverting, and directing the forces of nature to the uses and benefit of man—such is the engineering profession.

Through a review of history we must be impressed with the fact that ignorance, and its ever present boon companions, superstition and arrogance, have been the chief and most unflinching enemies to all progress and to all efforts ultimately designed for the benefit of mankind. When we recall the lives of Galileo, Voltaire, Smeaton, Watt, Stephenson, and even one who lived as late as Fulton, we must be impressed with the devotion and heroism which these men displayed, especially in times when to proclaim a new principle evolved, or a practical application or a science secured, meant persecution for witchcraft. They, as the intellectual lights of their age, knew full well their duty, the enlightenment of the world, and its redemption from savage lethargy; and accepted the task even at the threatened sacrifice of their lives.

Men like these, if we could have been honored by their existence in our age, would be classed as Engineers, in their several specialties. They stand now upon the pages of ineffaceable history, as the fathers of the applied sciences, and as such, we owe them the reverence due the founders of the engineering profession. The names I have mentioned are but a few of those, who, by their fortitude and by their desire to advance the cause of civilization, were willing—yea anxious, to sacrifice themselves upon that altar, which in their day, meant persecution for a principle.

The heritage which they have left us possesses a foundation broader and more deeply seated than that of any other profession. Its resources are illimitable; and the most fertile imagination fails to convey a fitting conception of its future triumphs.

Such names as the Roeblings, Holly, Eads, Flad, Howe, Trautwine, and others, are ever in our minds, as stimulating incentives to greater effort. Their work has been grand in conception, and practically faultless in execution. The majestic bridges, which carry millions of human lives and untold tons of freight across deep and yawning chasms; the tunnels, miles in length, which have removed the barriers of mountain fastnesses to commerce; and the harnessing of the mighty Niagara, and other rivers, all show the accomplishments of the engineering profession, and suggest the possibilities of its ever grander future.

While, as Engineers, we have no fear of the results from a comparison of our achievements with those of the other professions, yet, as one who has served something like twenty years in the varied branches of engineering, I would ask whether we have secured from the public that full recognition and emolument which the importance of our profession would seem to justly demand.

In our own State it might appear, at times, that our want of interest and aggression in political life had withheld from us a proper recognition in public affairs. In reviewing our history we find that Engineers, and even Architects, are not considered useful or necessary, as members of a Capitol Site Commission, or of even a Capitol Building or Irrigation Commission, the appointing power evidently preferring to make the Architect and Engineer, simply an employee, or subordinate to the Commissions. Bills have been before our Legislature, upon several occasions, which also failed to recognize the Engineer as a proper person to place upon State Commissions dealing with engineering questions. In a proposed bill for the purpose of establishing a comprehensive irrigation system for the State, more than 75 per cent. of the work to be done by the Commission would have been of an engineering character; and yet the framers of this bill would recognize none of the arguments made in the hope that they might appreciate the importance of having some engineering ability in such a board to suggest methods of procedure and plans. The public, as a class, seems to regard an Engineer as one better fitted to take directions, and to be in a subordinate position to a Board or Commission, than to sit with such a body as a full member, and have a full voice in the deliberations and in the framing of an intelligent plan of procedure.

From my standpoint, I fail to see any reason why the Engineers of our day, who are better educated, upon the average, than members of any other profession, and who must devote a longer time to the practice of their profession before they are deemed sufficiently proficient to take charge of important works, should not be fully recognized in public affairs, and especially upon those Government and State Commissions where their special training and knowledge would be of great service to the public.

Our Society should have noble aspirations upon such subjects; and I have deemed it proper to bring these questions to the attention of our members, in the hope that they might engage some earnest thought and inquiry upon your part, and at this, or some future occasion, a general discussion. An intelligent public must acknowledge that the Engineers of this day are as patriotic to their country, and as loyal to their profession, as those grand men of history to whom we are indebted for initiating our calling; and I most sincerely trust that the Montana Society of Civil Engineers—a most worthy and honored representative of the engineering profession—will ever use its voice and influence in earnest endeavors, exerted in the interests of the proper development of the illimitable resources of the State of our adoption, and for the fitting recognition of the engineering profession, which should, of right, be foremost in the attainment of the grandest results.

ANNUAL ADDRESS AS PRESIDENT OF "THE TECHNICAL SOCIETY OF THE PACIFIC COAST."

By George W. Dickie.

[Read before the Society, February 7, 1896.*]

The Society having in the usual manner expressed its desire that I should continue for another year as its executive head, I must take the opportunity that the occasion offers to express my appreciation of the honor conferred on and the confidence reposed in one who is not by any means the best qualified member of this society to occupy the place of honor.

In taking up this work for another term I desire to express my obligation to the late Board of Directors for their faithful work in connection with the varied interests of our society. By their efforts we find ourselves, at the beginning of another year, in a very much improved financial condition, with a fair prospect of being entirely rid of a debt which has hampered the work of the society for several years.

The arrangement made during the past year, whereby our society joined the Association of Engineering Societies, has enabled us to resume the publication of our transactions in the Journal of that Association. It is hoped that this action will be the means of stirring up a more lively interest among the members, both resident and non-resident, in the work of the society.

Of late some difficulty has been experienced in getting members to prepare papers to be read at the regular meetings of the society. This is unfortunate, and a strong effort should be made this year to remove this difficulty. The main object of the society's existence is to provide the means of permanently recording for mutual benefit the experience of the members in the various branches of our profession. I am well aware of the difficulties that beset busy professional men, and the lack of leisure that prevents many able men from recording their experience for the benefit of others, and I must also acknowledge with shame that many of our brightest professional men are bound by force of circumstances to labor on without respite on work that other men get the credit of, and their silence in regard to the work they are doing is the price they must pay for the chance to earn a living. It is this shameful condition, prevailing to so large an extent in this country as compared with other countries, that makes the transactions of foreign societies so much richer in practical experience than our own. I find that corporations, usually very stupid, and therefore

* Manuscript received March 23, 1896.—*Secretary, Ass'n of Eng. Socs.*

very selfish, are possessed with the stupid and selfish idea that because they employ an engineer to plan or carry out some unusual work for them, that the experience he has gained in so doing is their property and not his, and he must on no account give any of it away for the benefit of his professional brethren, for, might it not be used for the benefit of some rival corporation just as stupid and selfish as they are? Our transactions in the past years of the society's life have compared favorably with those of any other society of its membership in this country; but in order to show that we are growing in experience as well as in members, the record of our doings must keep pace with our advance in the practice of our profession.

While speaking of the recorded work of this society, I have to express my own sorrow, and in doing so I am sure that every member of this society feels the same deep regret, at the announcement made in the last number of *Industry* that that monthly is to be abandoned. I have been afraid of this termination to the life of *Industry* for some time, as I knew that Mr. Richards was carrying a greater load than his strength was equal to. That journal has been practically all his own work, and only those who have done such work can realize what that means. *Industry* did much for this society, and we shall feel very keenly the want of the stimulus that comes from the help of such a journal. I trust that some way may be found whereby we may still have the benefit of the recorded experience of our able member and ex-President, Mr. Richards.

The past year has been one more productive of experience than profit to the engineer. Many of our members have had to cultivate the virtue of patience and practice the science of waiting for something to turn up to a far greater extent than was good for them or the profession. Still, this State is immensely rich in natural resources and most of these resources are as yet undeveloped. Capital in the future will be invested with greater care than it has been in the past. Better and more permanent engineering works will be demanded in the near future in all branches of industrial development, and I feel certain that out of the present financial and industrial depression, lasting good will result to the engineering profession.

The advances that are being made both in the chemical and mechanical branches of mining engineering are of great importance to the Pacific Coast, and more activity is now apparent in our mining industries. This will give fresh opportunities to our engineers, opening up new fields for enterprise.

The electrical reduction of ores, the transmission of power by electricity from its natural source to the point where it can be profitably applied, the generation of electric currents for all purposes of light and

power still continue to give our mechanical engineers and electricians all the opportunities they can utilize for advance in an art that is just beginning to show its possibilities. The element of mystery ever present in all applications of the electric current as a means of transmitting power, has made it the ideal source of everything miraculous to the public. The great losses that so often result from its application to purposes unsuited to the nature of electricity, being invisible, do not strike the man who pays the bills so forcibly as a leaky steam or air pipe, or a bursted hydraulic main; so we often find our old and faithful pneumatic and hydraulic servants discarded to make room for the bright, new and lively electric man of all work. Yet the cost of doing the work is not always decreased by the change. The general opinion to-day appears to be that it will not be long before all the applications of power for the production of mechanical movements will be made through the electric current as a means of transmission. I do not concur in this opinion; but I believe that in all mechanical movements which the electric current naturally can produce without too much gearing, it will be the medium of transmission of the future. Where the transmission can be properly and economically made by the means of electricity it will be made and improved as experience develops it; but many operations now being attempted through electricity as a means of transmission will, after the limitations of this agent are better understood, be abandoned and the older methods will find many places where they can give better service than even the harnessed lightning. So I would not advise our younger members to neglect everything else for the study of electricity. There will always be a place, and a large one too, for thermo-dynamics, pneumatics, hydro-dynamics, as well as electro-dynamics, and he who puts all his faith in the universal efficiency of copper wire to perform every mechanical function, may some day receive a shock, and be forced to admit that even the electric current will not always go in the direction that is desired.

Our society has just made a beginning in a very profitable field of engineering that I trust may be extended so as to embrace all materials that are natural products of the Pacific Coast. I refer to the committee that we have just appointed to gather data and formulate it into a report on all the physical properties of our Pacific Coast timbers, with a view of providing information that can be accepted as trustworthy by all those whose practice requires an extended use of these materials. This committee being composed of both scientific and practical men who have already given much time and thought to the subject, their report will no doubt be accepted as authoritative, and help the extended use of this valuable product of our coast.

I should like very much to see a similar committee appointed to

report on the properties and values of the various building stones both natural and artificial, found or manufactured on the Pacific Coast. Correct data on this important subject is very much needed by all those who in their practice have to employ such materials and I trust that we may soon see our way to take up this subject.

As a body of men whose success is entirely dependent upon the commercial and industrial prosperity of that portion of the United States facing the Pacific Ocean, what encouragement and hope can we gather from the present indications of what the future has in store for the Pacific Coast? I base what hope I have for the future prosperity of the Pacific Coast not so much on our undeveloped natural resources, for they will never develop themselves without man's labor backed and supported by his enterprise, as on the evidences that I see to-day among all classes of business people of an awakening to the realization of the conditions that confront us, and a common desire on all sides to get together for intelligent study of all commercial and industrial problems that must be solved before permanent prosperity will begin.

We have reached a point in the history of this community when our state and municipal legislation must perform other functions than that of planning ways and means of increasing taxation. Industries that naturally should flourish among us should be fostered and sustained by wise laws. When we discover that the tax-gather is driving what should be a great industry away from our shores to another state or another nation, which is wise enough to keep the tax-gatherer away from a business that when taxed in one place simply moves to another, we had better consider whether we had not better keep our trade and forego the taxes than try to gather taxes and lose both.

That these questions are now in men's minds, not yet clearly, but getting brighter as they are thought over, is my hope for the future. The recovery is to be slow, and I think painful, because the disease is deep rooted. Our people must learn that commerce and industry is the foundation for the prosperty that abides. Speculation and debt is what we have been trying to subsist upon, and the man who has the biggest debt among us is the one we serve and acknowledge as king. This is not a fancy of mine but a fact, and to reverse that fact is the work that the men who seek to save the Pacific Coast must accomplish or fail.

EXPERIENCES IN AN ENGINEER'S PRACTICE.

By Walter P. Rice, Member of the Civil Engineers' Club of Cleveland.

[Presented before the Club, February 11, 1896.*]

In making the Petrie Street bridge improvement, the city of Cleveland constructed a large fill 60 to 70 feet in height across the valley, and a plate-girder crossing over the railroad tracks. The brook in the bottom of the valley had to be taken care of by a culvert. It was during the winter, and at a time when the Chamber of Commerce was passing the usual resolutions about helping the poor, and the cry was to afford work to unemployed men.

We made two designs, one for a stone culvert and one for a cast-iron culvert 6 feet in diameter. The argument was used that in winter it was difficult to get stone, and this meant delay; and the city wanted to adopt methods which would put the greatest number of men to work immediately. It was finally decided to go ahead with the cast-iron culvert. The pipe was 6 feet in diameter and about 2 inches thick, cast by The Variety Iron Works Co., of this city. I am not sure whether it was in 6- or in 8-foot lengths, but think it was in 8-foot lengths. When we came to investigate the question of proper thickness for this pipe, we could find no information in regard to the use of pipe of that diameter, and we were at a loss to form a correct estimate of the proper thickness. We took what we thought to be an extreme precaution and considered pressure in certain directions on the assumption of hydraulic pressure. After estimating the pressure, we found plenty of formulæ with regard to internal pressure, but could find nothing satisfactory as regards resistance to external pressure. We used the best information at hand, in the shape of a German formula, and concluded that a thickness of 1½ inches was ample. We added what might be called a factor of ignorance, and made it 1¾ inches; and the manufacturer added another factor to increase the amount of his bill, and it was cast almost 2 inches thick.

The foundation under the entire fill was very good. We struck one bad place at the edge of the fill, where the soil was soft. I left directions to take out all the soft material and refill with wet sand, tamped in layers until sub-grade was reached, and then to put concrete on top of that. This I supposed was done, although I was not there at the time. After the foundation had been prepared, a bed of Portland cement

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concrete, 9 feet wide and 18 inches thick, was laid, the pipe put in place, and the concrete carried up to the spring line, where it was 9 inches thick on each side of the pipe. From this point the concrete was finished tangent to the circumference. Orders were given to have the fill deposited in layers and tamped for a width of not less than 25 feet over the culvert, and I have no reason to suppose that it was badly done. Some time after the fill was constructed, in making an examination of the interior of the culvert, which is several hundred feet long, I found four lengths of pipe all adjacent or contiguous, cracked longitudinally top and bottom. For instance, there was a longitudinal crack on the top and bottom, running the entire length of four sections. Upon taking measurements, I found that there was a difference of four inches between the horizontal and vertical diameter of the pipe. We put in temporary bracing until the fill got through settling. The entire fill was made with more than usual care, and as the settlement was not at all excessive I cannot account for the failure of these four lengths. If they had not been adjacent to one another I might have thought that it was due to flaws or initial strains in the material; but the pipes were contiguous. The material was first class and subjected to the usual transverse tests. I can only make this one supposition: The fractured pipes were in the neighborhood of where we found the pocket of soft material. The inspector claimed to have had all of same removed, and there was at least 3 feet of fine sand and 18 inches of Portland cement concrete under the pipes at this point and the material over the culvert was tamped before the fill was made. The law of transmission of pressure in a fill of this sort and the law of resistance of the cast-iron ring under such conditions have always been interesting questions to me. What is the law of pressure? What is the law of resistance under these conditions? Apropos, I observed a curious thing with regard to external pressure in the current apparatus used when I was with Col. John M. Wilson on the gauging of the Cuyahoga River. It was simply an annular ring or submerged float with air space. It was sunk in rather deep water, and being made of tin, it collapsed under the pressure. In that case there was pressure all around the circumference. When the submerged portion was brought to the surface, it had been flattened, producing three sides of a perfect pentagon. The entire question is one that is extremely interesting to me, and one upon which I have been able to obtain very little light.

Incidentally, in connection with this, I might mention that on account of conflict with property holders at Petrie Street fill, the drainage or storm-water sewer which we had intended running down the side of the hill, along the edge of the city's slope right, had to be located in the fill itself nearly 60 feet above the brook into which we expected to

discharge. We used a drop man-hole, similar to an earlier design by Mr. Force, except that the foundation and details were somewhat different. So far as I know, this is one of the highest in existence, being 70 feet high, with a series of steps of stone flagging to break up the water every 4 or 5 feet all the way down. We used steel I-beams and concrete for the foundation of the drop man-hole, and the connection with the culvert was made with an iron pipe. Two sleeves were provided in this pipe, and clay was puddled around the joints to allow for any inequality of settlement between the culvert and drop man-hole. After settlement, we closed up the sleeves with Portland cement.

We had some trouble with settlement of pedestals on the Central Viaduct, in the neighborhood of Central Way. Strange to say, the amount of settlement gradually decreased towards the river. It finally assumed such proportions that I thought something must be done. I think the maximum settlement was in the neighborhood of $9\frac{3}{4}$ inches. A great many of the bents had settled, and it became noticeable on the bridge itself. Water stood on the bridge floor, otherwise it would not have been noticed by the public. We desired to raise it, and did not want a lot of sensational articles in the newspapers; so we undertook to raise it with our own bridge gang without making it public. We secured the money under some very harmless resolutions. The newspaper men were there, but being for repairs they did not comprehend it. A careful profile was made, showing the exact settlement. Instead of bringing them all up to the grade line, we brought them two-thirds of the way up, and at a very slight curvature that would not be perceptible to the eye, and then calculated to raise each one up to that curve. I think we raised 18 bents, and this was all done with travel (motor cars, etc.) going on overhead. We had a total height of 83 to 85 feet from cap of pedestal to roadway, and 108 tons to lift on each leg of the bent, the leg being composed of two channels latticed. It was almost impossible to get any purchase anywhere to make such a lift. We had a stone cap 5 feet 8 inches square, with a beveled edge, and only 12 inches, including a 4-inch wash on each side of the post, to get our purchase for the 108 ton lift. We finally decided on a method, using very simple apparatus. Short upright wooden bents were erected upon blocks on the stone caps and wooden cross-caps on top of these supported the I-beams which carried eight rods $2\frac{1}{2}$ inches in diameter. Reinforcing plates with a $5\frac{1}{2}$ inch bored pin-hole were riveted to the web plates of the post at a convenient distance below the I-beams and match holes were then bored in the webs with a tool made especially for the purpose. A $5\frac{7}{16}$ inch pin was slipped into place, cast-iron bearing-blocks on top of heavy channels were fitted up under the pin close to the webs of the post, and the channels then connected to the rods mentioned. The

men worked on a platform, and each one gave a certain number of turns to the nuts on the eight vertical rods. As fast as a bent was raised 1 inch a steel plate was slipped in, and when the proper height was reached cast-iron bases were put in place. Of course, we had to make certain adjustments in the trusses as the work progressed, but the entire structure was lifted without attracting attention. We were, however, working in very tight quarters. After the work was done, the city kept track of it and found some further settlement. This led to making borings which developed a rather strange state of affairs. We found, for instance, at one of the pedestals, 3 feet of sand, 4 feet of cinders and water, and 4 feet of clay and sand, in which the footing rests; then we found 10 feet of logs, soft clay, water and peat; 6 feet of sand and soft clay; 4 feet of very soft clay and logs; 3 feet of clay and very light sand; 4 feet of clay and sand; 1 foot of clay and water; and then coarse gravel and water. The borings in the neighborhood of the other pedestals were very similar. The indications all seemed to point to an old channel of the river. The same question of the transmission of pressure through soils comes in again. If that pedestal has gone down 9 inches, what action has taken place? How does the clay act? How is the pressure transmitted? The foundation is in the clay. If there is a hard stratum below and a soft stratum between, does the top stratum of clay act like a beam? Is that possible? In other words, if we have a fairly firm stratum of clay and then soft material superimposed upon hard material, is it possible that, as the pedestals sink down, the surface rises on account of lateral pressure in the direction of least resistance? That the material rises at a point of circumference outside the pedestal and depresses under the same? Is it possible that such a stratum can act in a manner similar to a beam? Under such conditions, which is the wiser course—to attempt to reduce the pressure by spreading further, or to break through the solid stratum and attempt to go down to a firmer bearing?

THE PRODUCTION OF DIPHTHERIA ANTITOXIN.

By Dr. Theobald Smith, Pathologist of the Massachusetts State Board of Health.

[Read before the Boston Society of Civil Engineers, February 19, 1896.*]

There is to-day among the various branches of scientific research a solidarity which makes it possible for me to be present here to-night to speak upon a subject of pure biology quite remote from the daily interests of your own profession. The biologist deals with what many of us choose to call the principle of life, whose activities do not as yet admit of that nice computation, that clever accuracy, realizable in the departments of physics and chemistry; and yet the mysterious processes of life are after all explicable and measurable only by the same standards and units which are common to all natural science. Life expresses itself to us in physical and chemical phenomena, and the progress of biology is marked by the gradual adoption of chemical and physical units. Here is the common ground of all research. The practical relationship between biology and engineering in the field of sanitation is too well known to bear more than a passing notice. The progress made in the prevention of disease from the biological standpoint exerts a strong pressure upon the views and methods and products of the builders of great cities, of great water-works, and of stupendous sewers. I shall not, therefore, in view of this close relationship, hesitate to present the details of the subject before us as minutely as I would to a body of specialists devoted to biology in its medical and sanitary aspects, trusting that this attitude will meet your approval.

The old theory which appeared with the discovery of bacteria, twenty or twenty-five years ago, insisted rather upon the mechanical action of bacteria, their obstruction of the bloodvessels and of the lymphatics of the body; but in the course of the great many investigations which have been made since that time we have come more and more to the theory that bacteria act not through merely mechanical effects, but that they act through chemical substances which they either manufacture or which are present in their bodies, and which are to the animal organism poisons—some of them very virulent in their nature.

To ward off the injurious action of bacteria, the body has at its command certain defences, certain means of protection. It has, in the

* Manuscript received March 19, 1896.—*Secretary, Ass'n of Eng. Socs.*

first place, the opportunity to destroy the bacteria themselves. In the second place, it has the opportunity of neutralizing or destroying their poisons. These poisons are known to-day familiarly under the name of toxins. We have, therefore, the two forces, the bactericidal and antitoxic effects, which are now being investigated quite exhaustively. In point of time the bactericidal was first observed. Metchnikoff, the great Russian biologist, is the most prominent figure associated with the evolution of our knowledge of bactericidal forces. It is he who first presented that doctrine, familiar to all of you undoubtedly, of the fight between the animal cell and the invading bacteria. He traced the development of these activities, which he called phagocytosis, through the lower invertebrates up into the mammals, and up to the present time he has been defending the theory of phagocytosis against the encroachments of another theory which I will present this evening. In spite of his brilliant researches and his advocacy of the theory of phagocytosis, there have come to the front studies which show that the bacteria are not always destroyed within the cells which take them up, but that the forces which destroy the bacteria in the body are largely extra cellular.

The knowledge of antitoxic forces could only be developed after the study of bacterial toxins had made some progress. It was not until 1888 that toxins were first definitely studied by Roux and Yersin, of the Pasteur Institute at Paris. These investigators showed that not only the diphtheria bacillus itself could produce diphtheritic affections and paralysis in animals, but that the culture fluid in which these bacilli had multiplied and from which they had been removed could produce a fatal toxic disease. Here we have demonstrated for the first time the existence of bacterial poisons which may act quite independently of the germs which produced them. These poisons could be precipitated from the culture fluid, dried and redissolved in water without losing their pathogenic properties. These were destroyed by heat, sunlight and a variety of other agencies. This important work furnished medical science a satisfactory explanation of the symptoms of diphtheria in man. A local vegetation of bacteria in the throat to produce such pronounced constitutional disturbance must act through some soluble poison absorbed into the body from the seat of the local disease. The extremely poisonous nature of this bacterial product may be appreciated when we bear in mind the fact that since then cultures have been found so virulent as to prove fatal to guinea pigs when only .005 of a cubic centimeter of the filtered fluid is injected under the skin.

In 1889 another bacterial poison was discovered, which proved even more fearful in its effect on animal life than the poison of diphtheria. Kitasato, a native of Japan and a pupil of Koch, has done

more than any other in making us acquainted with this poison. The disease known as tetanus was shown by him to be due to a bacillus of peculiar character, upon which I need not dwell here. After having mastered the difficulties surrounding its isolation from wounds, he found that even after the culture fluid had been passed through a Chamberland filter in order to deprive it of all living tetanus bacilli, a very minute dose was sufficient to produce in various animals the whole train of symptoms characteristic of tetanus. But, more than this, the blood and serous fluids of those animals which succumbed to this poison contained enough of it to produce the same disease in a second set of animals.

We have thus the remarkable phenomena of two diseases produced without the presence of the germs, simply by their products. And what are these products? While Roux and Yersin regard them as enzymes, the German observers have regarded them as albuminous in nature and given them the name of toxalbumins. I think there is no doubt that they are albumens and not enzymes or ferments, because we can graduate the dose very carefully which will destroy a guinea pig, and this dose remains constant for months in the laboratory and is used as a standard in testing poison for the antitoxin serum. The toxalbumin of tetanus is quite sensitive to light and to temperatures above 55° C. It loses its virulence when dried at the temperature of the blood in the thermostat. It remains unaffected when water is added, but is speedily destroyed by chlorhydric acid in less than one-half per cent. solutions.

Among the many pathogenic bacteria which have been studied these two stand out pre-eminently as toxin-producing. Though poisons are demonstrable in cultures of most if not all pathogenic forms, their action is feeble as compared with these. This fact, togther with certain other differences, emphasized the division made some years ago by Koch between the infectious and the toxic diseases. The bacteria producing the infectious diseases multiply within the organs of the body, whereas those which produce the toxic diseases remain outside of the body; in the throat in diphtheria, in the wound in tetanus, and by the diffusion of their poisons manufactured in these places completely subdue the resistance of the body.

So much for the investigation pointing to the existence of soluble poisons which leave the bacteria and diffuse themselves throughout the culture fluids which we employ. In 1890 the doctrine that antitoxins exist in the body first became known through researches made in Koch's laboratory by Behring, who is now known to all of you as the real discoverer of the principle of antitoxic substances. In December, 1890, Behring and Kitasato announced the new principles as deduced from their experiments with the poison of tetanus as follows:

The blood of rabbits made insusceptible to tetanus possesses the power to destroy the poison of tetanus.

This power resides in the extravascular blood as well in the blood serum free from cells.

This power is of such permanent nature that it remains active in the organism of other animals. It is thus possible to produce pronounced therapeutic effects by the transfusion of blood or serum.

Thus the principle was established, but there were a good many practical difficulties in the way of its immediate practical application, and it was only several years ago, I think in 1893, that serum was produced in sufficient strength to be used in therapeutics. At first sheep were used for this purpose, but the antitoxic power of sheep's blood remained quite low. Then horses were used, and they are still used to-day because they produce a very effective serum, and because they can stand the withdrawal of a large amonnt of blood.

In regard to the choice of horses, there is of course considerable difference in their behavior towards the treatment which produces antitoxin. The high-bred horse, the sensitive horse is an animal unsuited for this purpose, and it seems that those that are very stupid are also unsuited for other reasons. The high-bred horses will die from the effects of toxin if the dose is graduated a little too high. Horses of the other type do not show any reaction, do not care about the quantity of toxin injected, and consequently do not furnish any antitoxin that is worth preserving. The method as practiced on the horse is simply as follows: An animal is treated with the poison of diphtheria for from six to eight months, with increasingly large doses of toxin, until his blood yields the desired strength of the antitoxin.

The toxin is nothing but a broth culture of the diphtheria bacillus, from five to fifteen or twenty days old, from which the bacilli have been removed by filtration through a Chamberland filter and the clear fluid used for the injection. The ordinary culture flask which we use is one of this shape which I show you. This shape is chosen so that we may get a large surface of fluid in contact with the air which the diphtheria bacillus needs in the production of toxin. These flasks were devised in the Pasteur laboratory, to permit the suction of air through the flask while the culture was growing. It was thought that the bacteria needed oxygen plentifully, and consequently an aspirator was attached to this end and the air was drawn through. It has been found, however, that this is not necessary, and, as a matter of fact, the continuous current of air is injurious. The workers in the Pasteur laboratory obtained, apparently, a very weak toxin. We now use toxins ten to fifteen times as strong, largely because we have improved upon the methods which they suggested.

Now let us turn to the antitoxin. When the horse has been treated with the toxin subcutaneously for from five to eight months he acquires an immunity to the poison and can stand larger and larger quantities. There is always some swelling at the point of inoculation and a slight rise of temperature. But as the dose increases, as he becomes more accustomed to the poison, the temperature reaction is feeble and the local swelling disappears, so that a horse can stand at one injection enough toxin to kill an army of 10,000 guinea pigs, and can stand a dose of toxin which would kill probably 15 or 20 horses if that dose were divided among such as had never been under treatment.

There is some change, therefore, which the system undergoes, by virtue of which the blood is enabled to neutralize the toxin which is injected into the body. When after a certain number of days following the largest dose which we have given, the blood is drawn, allowed to coagulate, the serum drawn off from the clot, and this serum tested, it will be found that it can neutralize a large quantity of the poison.

The drawing of the blood is a very simple process. The two external jugular veins are very near the skin in the horse. A trocar and canula is used. This one was devised in the Pasteur laboratory in Paris. It consists of this canula or tube through which passes this pointed trocar. A little incision is made through the skin, this trocar with canula is forced directly into the vein through the incision and the trocar then withdrawn. The blood will flow out through the canula and rubber tube connected with it into jars prepared for the purpose. The horse will pay no attention to the operation but will continue to eat the oats offered him while the blood is being collected. I have drawn on an average four quarts or litres at a time. The wound is closed with a few pins. The horse shows no signs of disturbance at any time after the bleeding. I should say here that every operation is conducted under the most careful antiseptic precautions. All the apparatus we use is steamed first or else heated in a hot air oven to a temperature of 150° C. if it can stand that. All our glassware is heated to that temperature. That which does not stand dry heat is boiled, and all instruments and tubing are boiled or steamed, in order to destroy all adhering bacteria.

The blood is allowed to stand for twenty-four hours, after which time a considerable quantity of serum has gathered above and around the clot and this serum is drawn off. In twenty-four hours after that another lot is drawn off, and in three or four days the whole serum has been collected.

This is next tested as to its efficacy. All serum must undergo this test before it can be used as a remedy, because it varies in strength from time to time, sometimes quite unexpectedly, to the disappointment of the

bacteriologist. The test has been brought to quite a considerable degree of accuracy by Behring. He adopted a certain unit, which is simply this. Ten times the dose of the toxin, fatal to guinea pigs of a certain weight (300 grammes), is mixed with a certain quantity of the serum, and this mixture of serum and toxin is injected under the skin of the guinea pig. If no local swelling appears and if the guinea pig remains active and shows no disposition to become ill, then that toxin, ten times the fatal dose, has been neutralized in some way or other by the antitoxin, and the quantity of antitoxin used is considered as one tenth of a unit. In actual practice we have been enabled to raise the antitoxin to such a degree of efficiency that .001 c. c. of the antitoxin would neutralize ten times the fatal dose of toxin. That is to say, if we mixed .001 c. c. of serum with ten times the fatal dose and injected it under the skin of a guinea pig, that pig would show not the slightest indication of any local disturbance.

I have brought some of the serum with me. It is as you see a pale amber fluid of great clearness. This bottle contains 10 c. c. and each c. c. contains 100 antitoxic units. This other bottle contains 20 c. c. and is half the strength of this. This is the strength usually sent out from the Pasteur Institute in Paris, but many horses will produce a stronger toxin, and of this, to produce the same result, only half the dose has to be injected.

We have now before us the vexed question concerning the nature and mode of action of antitoxins. The first theory which suggested itself to Behring is that of direct neutralization of the toxin by the antitoxin. When the fatal dose of poison and the serum are mixed in a certain proportion and the mixture injected into a susceptible animal, no effect, either local or general, is noticed. When the amount of serum in the mixture is decreased, local indurations appear, and when still smaller doses are used the injected animals succumb.

When the diphtheritic poison and the antitoxic serum are injected separately in different regions of the body, the latter some hours earlier, from thirteen to fourteen times this quantity of serum is needed to prevent any local indurations, and from five to six times the amount simply to prevent death. In spite of this apparently very definite evidence that the antitoxin neutralizes the toxin in this chemical sense, and thereby destroys it, observations are not wanting which militate against it. Roux discovered the important fact that when a mixture of the antitoxin and the toxin which has no effect on normal guinea pigs be injected into those which have been previously immunized against Asiatic cholera, the fatal effect of the apparently neutralized poison reappears. Similar results were obtained when guinea pigs had been exposed to other bacterial poisons. Behring has also observed a fact

which seems to contradict the neutralization theory. In the case of horses which were undergoing immunization he found that animals became after a time sensitive to a quantity of poison which a little of their own blood would promptly neutralize in a test tube. That is to say, when injected under the skin of another animal it would produce no result, while they themselves, that yielded this blood, became very sensitive. Evidently we are dealing here with factors which appear simple but are really complex, and the contradictory evidence concerning their theory of action must be attributed to a deficiency of knowledge which time will undoubtedly make good.

Without any stable theory of the action of antitoxins, it might appear useless to discuss their nature at this time, and I shall content myself with the simple statement of a few hypotheses. The specific nature of these protective substances, in virtue of which the antitoxin of diphtheria is powerless to overcome the toxins of diseased germs, other than that of diphtheria, has led Buchner to promulgate the theory that antitoxins are derived from the injected toxins; in other words, that the latter have been converted into non-poisonous, protective substances by the cells of the animal body. The antitoxins are, in this sense, simply bacterial products modified by the tissues of the body into which they are injected, and made capable of counteracting the poisons from which they are derived. Their wonderful action is on these grounds made simple by Buchner, who looks upon it as only a modification of the methods of vaccination in vogue for many years past, and therefore not an essentially new method. When the antitoxin acts after the disease has broken out, as in human diphtheria, he believes that it simply immunizes, protects or vaccinates those regions or cell territories of the body not yet affected by the poison, and therefore causes the disease to halt. The theory at first suggested by Behring would assume a neutralization of the poison already in possession of the field.

Whether the antitoxins are toxins transformed by the cell activity of the body, or whether they are weapons created anew by this same cell activity under the irritation caused by the presence of bacteria and their toxins, as is assumed by the French school, we must leave undecided. As regards their *modus operandi* it may be safely stated that the weight of evidence is against the theory of direct action of antitoxin upon toxin, and in favor of the theory that the antitoxin acts only by stimulating the powers of resistance of the body cells.

Another question which here presents itself is the nature of the immunity conferred by the antitoxins. When an animal is inoculated with attenuated or sterilized cultures of certain specific disease germs, it passes through a mild attack of the disease. There are fever and other symptoms of illness noticeable for a time. A second and larger dose of the

same culture may lead to the same transitory symptoms. Finally, after a series of such inoculations or vaccinations, the animal is able to withstand many times the fatal dose, and thereafter that animal is insusceptible. But when the serum is injected this is not the case. The animal itself does not pass through a mild disease by which it is able of its own accord to resist the toxin, but the injected serum protects it while the animal apparently remains passive. For instance, when antitoxic serum is injected into the still healthy children of a family where disease has broken out, these children do not contract the disease for some six weeks, because the serum protects them. But after that time a new injection has to be made in order to prevent infection. If those children had passed through the diphtheria disease itself they would have become sufficiently immunized to protect themselves subsequently, and in their blood antitoxin would be present. That is the difference between the active immunity of the disease itself and the passive immunity conferred by the antitoxin.

Now as to the application of antitoxin. This is a professional matter, and it is something into which I do not care to enter. I shall simply make a few statements in regard to its use.

There are two uses to which it can be put. The most important, of course, is the curative. The great difficulty in medicine is to cure disease after it has broken out. You can prevent diseases, but the cure requires a great deal more power or influence from outside through medicines or in some other way. It illustrates once more the old adage than an ounce of prevention is worth a pound of cure. So it is with the serum. The serum injected on the first day of the disease will more speedily break it up than if injected on the third or fourth day. Then it has only a partial effect, and larger doses must be injected in order to stop the disease from proving fatal or from continuing in its ravages.

Its action is not peculiar to itself. It is nothing more than nature's remedy manufactured under artificial compulsion by the horse, and transferred by the ingenuity of man to the body of the feeble child. The serum simply augments the forces of resistance, without adding any that are unknown to or radically different from those in the human body. The curative action must, therefore, proceed along the very paths followed by the human body in a spontaneous recovery. No unusual symptoms, no miraculous change, should be looked for, nothing beyond a quickening or acceleration of the favorable course. It is this fact which will make a true estimate of the remedy in many cases a difficult one.

Among the things which have been noticed by physicians is a more prompt removal of the membrane which forms in the throat, sometimes almost miraculously. It has also been noticed that where there

is a tendency, especially in very small children, for the disease to go into the larynx and produce a contraction of the aperture, causing suffocation and death, or where the tendency is to go down further and produce croup, or where there is a tendency for the membrane to go into the nose, a prompt injection of the serum stops this passage up or down, and saves a child which might have suffocated in a few days. It has been reported, especially from Europe, that that very severe operation which is known as tracheotomy, has become less necessary, on account of the check which the disease receives under the influence of the antitoxin treatment. This, of course, is a very great benefit, because the majority of the children that are tracheotomized die either from the enfeebled condition, or from septic results.

The remedy fails in very advanced cases, when the child is already run down by the saturation of the body with the diphtheria poison; and it also fails in very severe septic cases—cases in which other bacteria, which get into the body through lesions produced in the throat, assist in the destructive work.

In order to determine whether certain cases of throat troubles are diphtheria or not, a method has been very thoroughly worked out of late and is now practiced in this city by the City Board of Health, and in other cities by other boards of health. It consists in rubbing a little sterilized swab of cotton at the end of a piece of wire over the membrane or diseased portions of the throat, and then rubbing this swab upon coagulated blood-serum in a tube. This tube is placed in a thermostat at the temperature of the body. The next morning a little of the growth is removed with a wire from the surface of the serum and examined under the microscope. If the diphtheria bacilli appear, notice is at once sent to the physician having charge of the case. Not infrequently, especially in adults, only certain other forms of bacteria are found, and the case is regarded as one of false diphtheria. In a city where prompt communication can be had between a central station where these cultures are examined and the physician, the latter can often wait before the administration of the antitoxin till he gets his message. This of course is impossible in the country. But the method subserves another important purpose. It tells the family, even though a few days later perhaps, that there is diphtheria in the house and that sanitary precautions should be carried out as fully as possible to prevent its spread.

As regards the naked-eye appearances of the diphtheria cultures, I have brought one with me from the laboratory, in order to show them to you. I also pass around an uninoculated tube for comparison. The little specks upon the serum are what we call colonies of diphtheria bacilli, bacilli that have been planted there and multiplied and formed a mass visible to the naked eye.

Antitoxin is furthermore applied as a preventive, and I think that it will be used very extensively in the future for this purpose. If a case of diphtheria occurs in a family where there are a large number of children who cannot be isolated, as, for instance, in the great tenement house district of New York City, the serum is at once injected, in small doses, however. Not more than one-fifth of the dose which is passing around would be used as a preventive or vaccinating dose, as we may call it. This, as I said a moment ago, will protect a child for fully six weeks. After that, if the disease has not been stamped out, another dose would be necessary.

The remedy has also been found very useful in large establishments containing children. This has been found especially true in the hospitals and charitable institutions of New York City. Immunization or vaccination with small doses where diphtheria has appeared, has shown excellent results. I would say that New York City has been the pioneer in this matter, both in the culture test for diphtheria and in the free distribution of the antitoxin. Large numbers of bottles are distributed to inspectors, who either hand it over to the physician, or make the injection themselves whenever necessary. The inspectors also make the culture test from the throat, or else induce the attending physician to make it, as the case may be.

In conclusion I would say that the study of toxins and antitoxins is only begun and that there is promise from the principles first discovered by Behring of valuable practical results in diseases other than diphtheria.

THE SEWERAGE SYSTEM OF INDIANAPOLIS.

By Charles Carroll Brown, Member of the Engineers' Club of St. Louis.

[Read before the Club, November 6, 1895.*]

In 1870 Moses Lane designed, for the city of Indianapolis, a system of sewers, which was intended to serve about three thousand acres, the extent of the city at that time, with some allowance for growth. Up to 1891, sewers had been constructed draining most of the streets on about one-half this area. Prior to 1891, 19.9 miles were built at a cost of $663,900.67, and during 1891 and 1892, 8.3 miles were built at a cost of $66,620.76, making the total length of sewers constructed, according to this plan, 27.4 miles, and the total cost $730,521.76.

The city had largely expanded by this time, and in 1891 it covered 9,610 acres, much of the new area lying in a direction different from the direction of growth in 1870. A new system was therefore necessary to serve the new territory and to relieve some overcharged sewers in the district covered by the old system. Some of these old sewers were overcharged at their lower ends, though much too large at the upper ends, because they were made of uniform diameters throughout, those diameters apparently approximating the mean diameters for properly designed sewers on the lines. These sewers serve as examples of City Council engineering.

In 1891 the city was given a new charter by the provisions of which public improvements were put in the charge of a Board of Public Works appointed by the Mayor. Sewers are entirely under the control of the Board, although street improvements can be blocked by proper remonstrance, backed by the Common Council. One of the first steps taken by the Board of Public Works was toward plans for the additional sewers necessary. Preliminary topographical surveys were made, and Mr. Rudolph Hering was called in to make a general plan for the system and to advise as to the details of design and construction. Mr. Hering's report covers very completely the essential points and is readily obtainable.

I will now describe the work that has thus far been done, mentioning such details of construction as seem valuable, and giving the methods of letting contracts and collecting assessments, as they are in some particulars peculiar to Indiana and quite satisfactory in practical use. Reference should be made to the accompanying map and drawings.

There are four streams running through the city, viz., White River,

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Fall Creek, Pogue's Run and Pleasant Run, which, with the canal, divide the city into six drainage districts. See map, Fig. 1.

1. North of Fall Creek.
2. South of Fall Creek, formerly drained by the State Ditch.
3. Pogue's Run.
4. West of the Canal.
5. Pleasant Run.
6. West of White River.

These streams give economical methods of getting rid of storm water, so as to reduce to a minimum the size of the sewers necessary to carry the sewage of the new sections of the city round the old section to the river below the city. The plan in general provides for

I. Intercepting sewers.
II. Main sewers.
III. Local sewers.

I. An intercepting sewer is located on one or both banks of each stream in the first four districts, so as to receive all of the ordinary flow from the main sewers and a considerable part of the first storm water, and carry it down to the main intercepter, which carries the collected sewage of the first four districts mentioned to the river near the southern city limits. When the river becomes objectionable at the present outlet, the sewer can be extended farther down, or, if there is complaint from districts below the city, the sewage can be pumped into a plant for its treatment at the present mouth of the sewer or farther south. The main intercepter is completed, the White River intercepter and the Pogue's Run intercepter are under contract, and papers have been prepared for the intercepter for the north-east district. For the north side of Fall Creek an intercepter is proposed, which will cross the creek at Mississippi Street and discharge into the White River intercepter. The north-east intercepter will take the sewage from the proposed Manchester Street sewer and from the district along Fall Creek, on the south and east, and discharge it into the Fourteenth Street or State Ditch sewer. Thence it will flow into the White River intercepter, and thence into the main intercepter. Likewise the Pogue's Run intercepter discharges into the Washington Street sewer, the sewage flowing by way of Washington Street, Kentucky Avenue and Mississippi Street to the main intercepter.

The main sewers thus act at times as intercepters for a part of their course. On the other hand, the district west of the canal drains directly into the White River intercepter as its main sewer, so that the size of the sewer increases from 3 feet at its upper end to 6 feet 9 inches at Indiana Avenue. At this point an overflow is provided to take the storm water into Fall Creek, and the diameter of the sewer is reduced to

4 feet 6 inches, which is sufficient to carry the sewage. The diameter then increases gradually to 6 feet at Washington Street, as the storm water from the lower part of the district enters it. Another overflow is provided here, to discharge the storm water into White River, and the sewer is again reduced to 4 feet 6 inches and it so remains until the main intercepter is reached, as no additional storm water is permitted to enter.

Figs. 2 to 6 give some details of the junctions and overflow at Indiana Avenue as designed for the White River intercepter, and Fig. 7 gives the details of the connection of the Fourteenth Street sewer with the same.

II. As to main sewers.

(1) *The District north of Fall Creek* is just beginning to call for sewers. One sewer has been projected, but the Board of Public Works recently appointed has delayed its construction.

(2) *The District south of Fall Creek* has paid for the large State Ditch or Fourteenth Street sewer, the cost of which was $200,000 and for numerous branches thereto, and more will follow. There remain to be constructed the Manchester Street sewer and one discharging into Fall Creek near Central Avenue. Figs. 7 and 8 give some details of the Fourteenth Street sewer.

(3) *The Pogue's Run District.*—The Run flows near and through the principal business part of the city and the most densely populated part. There are therefore several sewers built and projected to discharge into this stream. It is not large enough to carry all the water coming to it, and there are also numerous obstructions in the way of bridge piers, foundations of buildings, arches, etc , which seriously interfere with the flow of water. On September 4th we had a rainfall of seven inches in ten hours, with about four inches of this in two hours, which brought the Run well out of its banks. This occurrence has renewed the discussion of plans for its improvement, and it is now proposed to straighten the stream and give it a cross-section such as is shown on Fig. 9. This work, complete, would cost about $600,000, and it is probable that it will be done in parts until the stream is found to be under control. Such floods as that of September 4th come but once in from ten to fifteen years. There were several interesting features in the construction of the Mississippi Street sewer, discharging into Pogue's Run at Merrill Street. Figs. 10 to 13 give drawings and photographs of some of these details.

(4) *The District west of the Canal.*—This district drains into the White River intercepter, now under contract and to cost $140,000. Several main sewers enter the intercepter, which is enlarged to provide for the storm water draining into it, and has overflows provided, as above described.

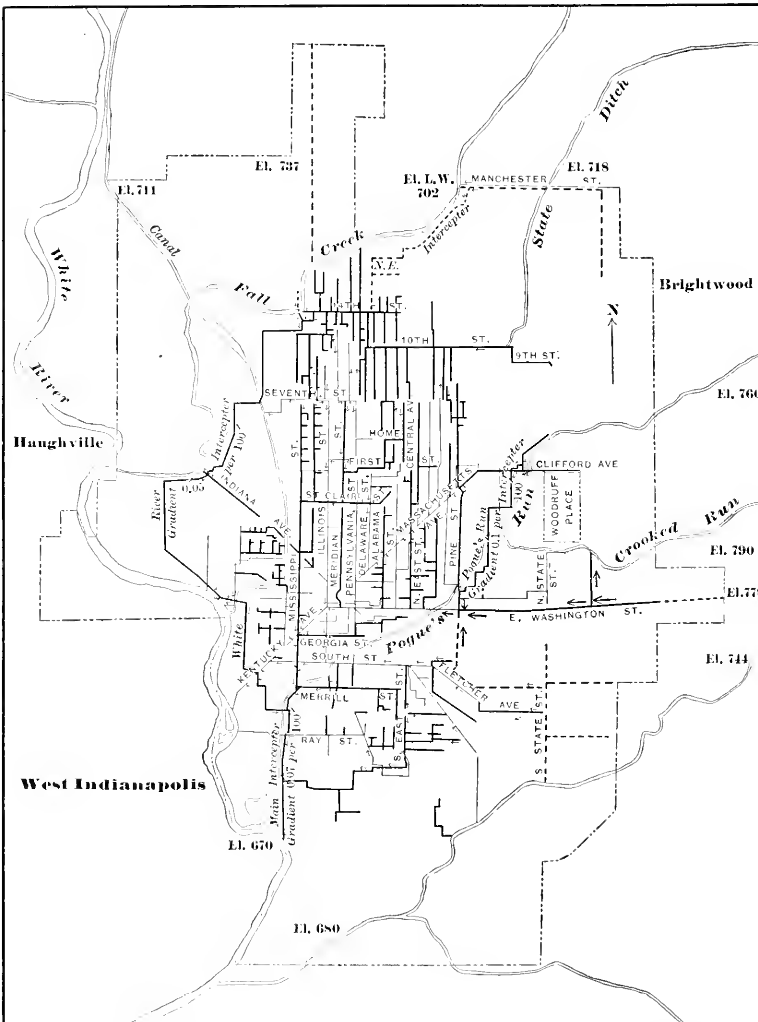


FIG. 1.—MAP SHOWING SEWERS CONSTRUCTED IN INDIANAPOLIS, IND., JANUARY, 1896.

Sewers constructed prior to 1893.
" " during 1893, 1894 and 1895.
" (main) proposed.
City limits.

(5) *The Pleasant Run District* is independent of the others and will be treated independently. At present there is no call for sewers except for the removal of storm water, and there will probably not be a very loud call for some years, as this portion of the city is not now growing very rapidly. An independent intercepter discharging into the river near the mouth of the Run must be constructed for this district.

(6) *The District west of White River.*—Most of the area west of the river is in the city of West Indianapolis and the towns of Mount Jackson and Haughville, so that it will be necessary to absorb these corporations or to go into partnership with them in the sewer business. Most of the area within the city limits is low, as is that immediately north and south of it, and can be drained into the river only at low stage of water. It will probably be necessary to pump the sewage from this area. Nothing will be done with the sixth district until there are further developments in the way of annexation. The principal street—Washington Street—is paved with brick, and an ample drain for carrying off the water from the street was constructed as a part of the improvement. Some of the property owners resisted the payment of their assessments for the construction of the street because they considered the drain not properly a part of a street-paving plan. The case was carried to the Supreme Court of the State, and the decisions have all been in favor of the method of construction and assessment followed.

Fig. 1 is a map of the sewers constructed and now under contract. The fine lines show the lines of the old system and the heavy lines those of the new. The projected sewers likely to be built at an early day are shown by dotted lines.

7.8 miles of sewers were built in 1893 at a cost of .	$148,887 60
20.0 miles were built in 1894 at a cost of	633,330 69
20 miles were constructed or put under contract in 1895 at a cost of about	400,000 00
Total of the last three years, 47.8 miles, costing	$1,182,218 29

making the total of the old and new systems about 75 miles, costing about $2,000,000.

The intercepters are named on the map and the main sewers will be easy to recognize in most cases.

The following are the principal main lines:

Of the old system, Kentucky Avenue and Washington Street to Pogue's Run, with its branches, South Street and Ray Street. The Kentucky Avenue sewer is intercepted by the new Main Intercepter, and also by the new Mississippi Street sewer.

Of the new system, the Mississippi Street sewer from Pogue's Run to St. Clair Street, thence east to Meridian, north to First, east to Alabama, north to Home, east to Central and north to Seventh; (This

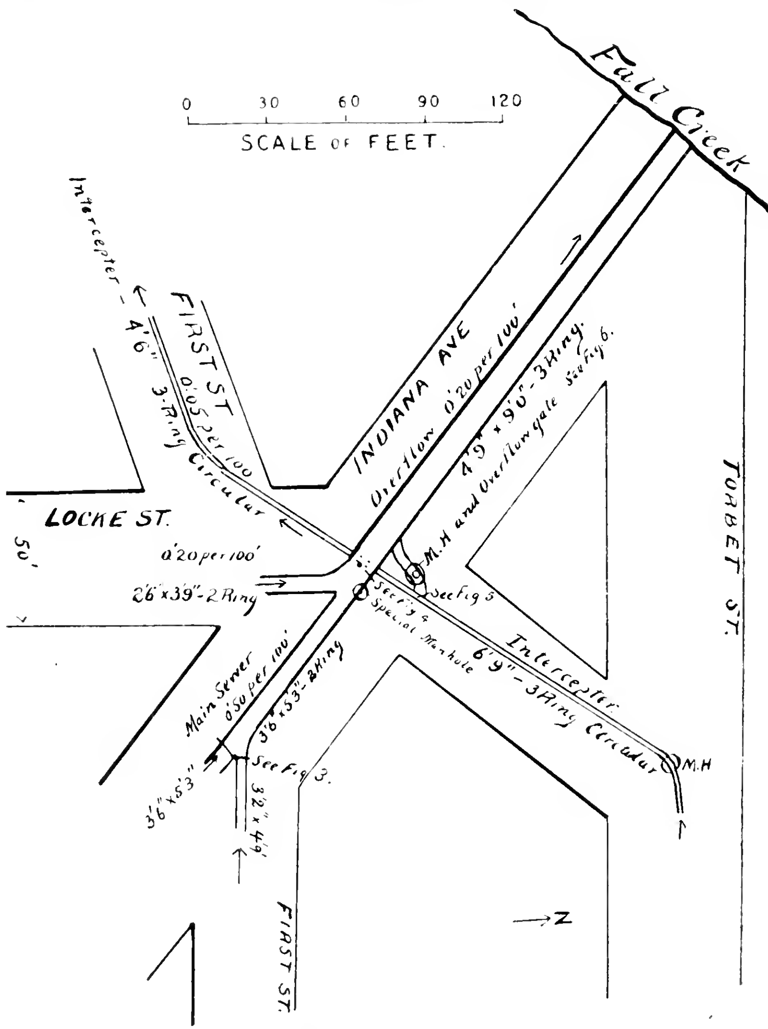


FIG. 2.—WHITE RIVER INTERCEPTER.

Indiana Avenue Junction and Overflow.

sewer cuts the old Kentucky Avenue sewer and turns the sewage down Mississippi Street, leaving the lower portion to act as an overflow for storm water. See Figs. 10 to 13 for details of the construction of this junction. It also cuts off the upper ends of the Illinois, Pennsylvania

and Delaware Streets sewers, and has several other branches, as shown); East Street, intercepting the old Massachusetts Avenue sewer, and having branches as shown; Pine Street and Clifford Avenue; East Washington Street; also the sewer marked Hill Street on the map which, for a short distance, takes the place of an old sewer of insufficient depth. All of these are in the Pogue's Run district. All of the principal sewers in this district are now constructed except one in and near Crooked Run and one for the district west of State Avenue and north of Fletcher Avenue. The State Ditch sewer, shown on 14th, Delaware, 10th and 9th Streets, in the district south of Fall Creek. The Manchester Street sewer, shown on the map as projected, would be constructed largely to relieve this sewer of storm water from a large district

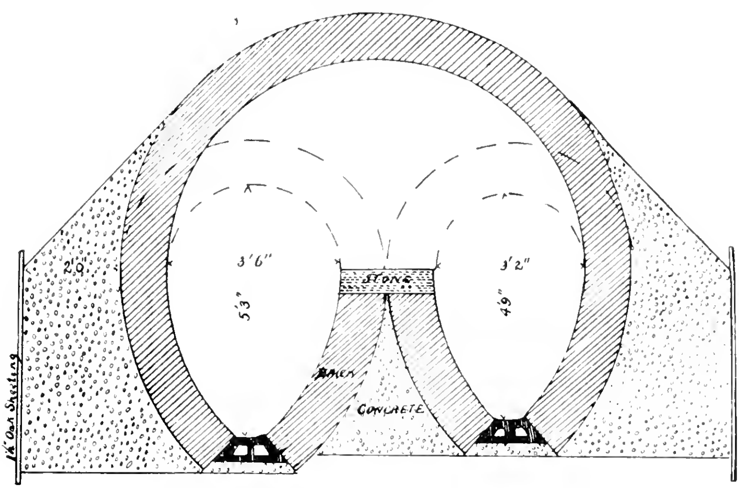


Fig. 3.—White River Intercepter.
First Street Junction. Scale, 1 inch = 4 feet.

outside the city limits. The number of main sewers, in the sense of the term thus far used, which remain to be constructed in the present settled portions of the city is therefore quite small, thanks to the activity of the last three years. Besides the projected main sewers, a number of local sewers will be constructed in the next few years, but they will all be small and inexpensive. In the resolutions for their construction some of them will be styled main sewers, as later explained.

Figs. 2 to 6 give details of the intersections and junctions at Indiana Avenue and Fall Creek and the overflow for the White River intercepter. Fig. 2 gives the plan of the sewers at this junction. The Indiana Avenue sewer, 3 feet 6 inches by 5 feet 3 inches, is the principal main sewer. It is joined by the First Street sewer, 3 feet 2 inches

by 4 feet 9 inches, without increase in its size on account of the increase in gradient at this point. When joined by the Locke Street sewer it changes to 5 feet 3 inches circular for fifty feet or so until the intercepter is reached. The intercepter is on a lower level, as shown, and the sewage from the Indiana Avenue sewer enters in by a 12-inch pipe, the storm water passing over the top of the intercepter into the common overflow for the Indiana Avenue sewer and the intercepter. The overflow for the intercepter begins just above (north of) the Indiana Avenue sewer intersection and takes the storm water from it. Fig. 3 shows a cross-section of the junction of the Indiana Avenue and First Street sewers, taken on a broken line at right angles to both lines. This is the standard form for such junctions.

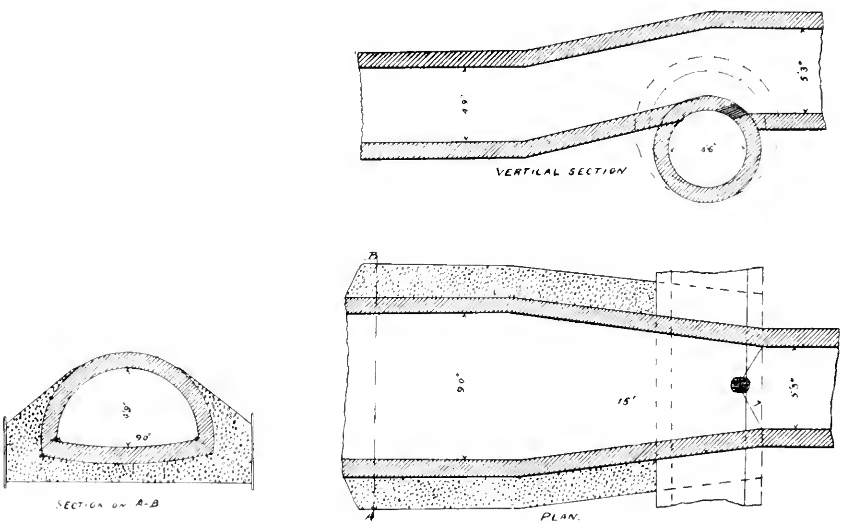


Fig. 4.—White River Intercepter.
Overflow of Indiana Avenue Sewer. Scale, $\frac{1}{12}$ inch = 1 foot.

Fig. 4 shows the connection of the Indiana Avenue sewer with the intercepter. The Indiana Avenue sewer is 5 feet 3 inches circular, as shown on Fig. 4 at the right. The bottom of the sewer is about 12 inches below the outside top of the intercepter. Just at the point of contact a 12-inch iron pipe is inserted in the intercepter to receive the ordinary flow of sewage. Storm water, when in sufficient quantity, overflows the dam formed by the projection of the intercepter into the sewer and flows through the overflow sewer to the creek. The height of the overflow sewer is fixed by the overflow from the intercepter, shown in Fig. 5, and the width is made sufficient to take the water from the Indiana Avenue and the intercepter overflows with as little head of back

water as possible. The form of the overflow is shown in the "Section on A–B" in Fig 5. Fig. 5 shows the intercepter overflow. The intercepter is here 6 feet in diameter. An opening is made in the side, 6

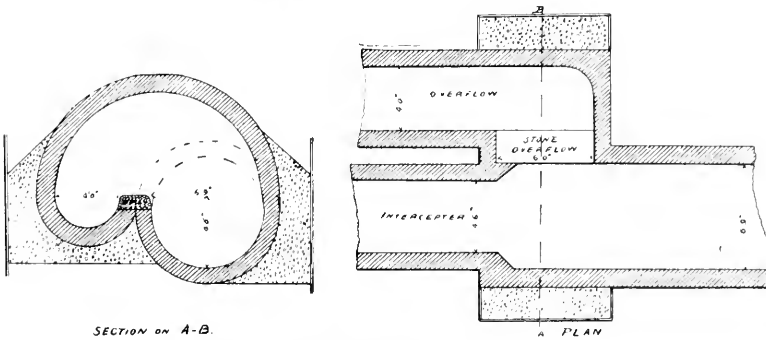


FIG. 5.—WHITE RIVER INTERCEPTER.
Overflow at Indiana Avenue. Scale, $\frac{1}{12}$ inch = 1 foot.

feet long and 4 feet 6 inches above the bottom, over which the storm water runs into the connection with the main overflow sewer 4 feet in diameter. In this 4-foot section is put a manhole and a back water gate to prevent water from the creek from running back into the inter-

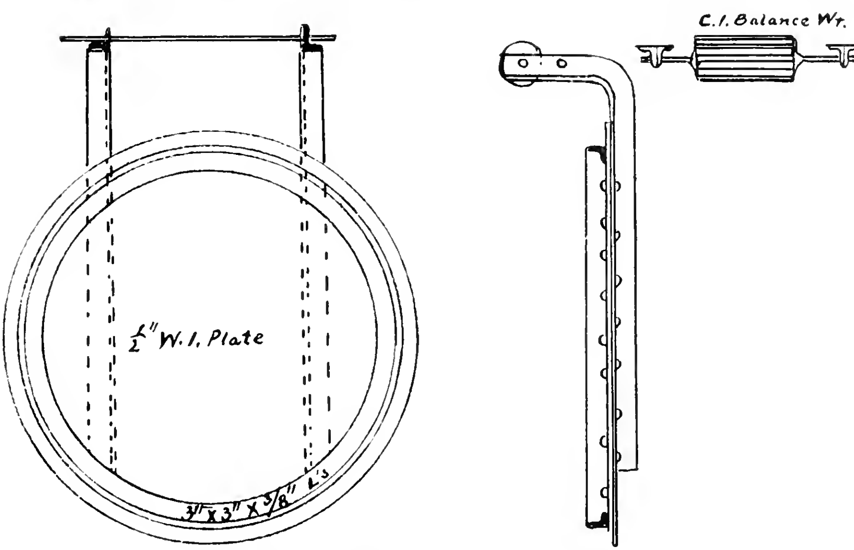


FIG. 6.—WHITE RIVER INTERCEPTER.
Overflow Gate. Scale, $\frac{1}{2}$ inch = 1 foot.

cepter when the creek is high and the intercepter is low. The intercepter reduces to a 4-foot 6-inch circular sewer immediately below the overflow. The gate referred to is shown in Fig. 6. Before water rose to the top of

this gate it would run into the intercepter through the 12-inch pipe in the Indiana Avenue overflow, shown in Fig. 4, but the pipe is small, and the back water from the Washington Street overflow into White River would probably reach to Indiana Avenue when Fall Creek was at this height, so no way of closing the pipe is considered necessary and none is provided.

Fig. 7 shows the connection of the Fourteenth Street or State Ditch sewer with the intercepter. The plan shows the curved form of the bed of the connection with the intercepter, which runs gradually down from the bottom of the main sewer to a point 36 inches below. The section

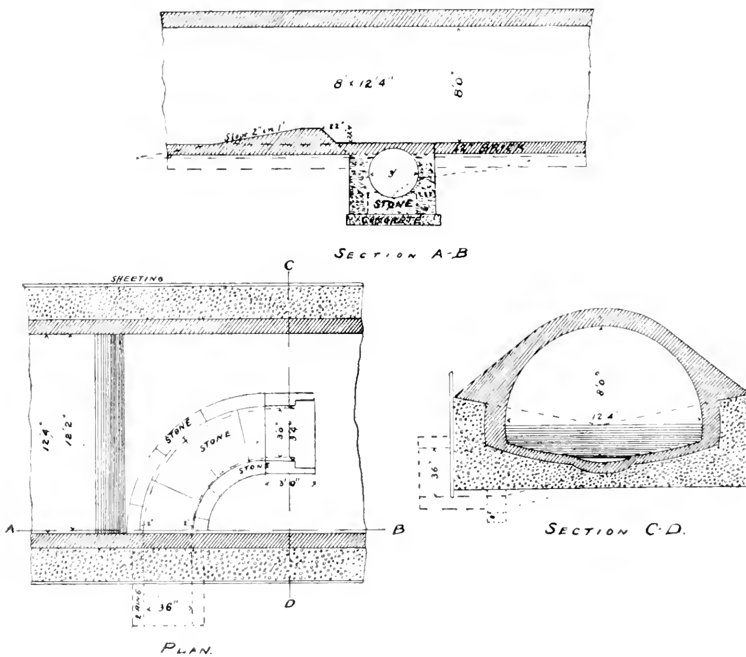


FIG. 7.—FOURTEENTH STREET SEWER.
Connection with White River Intercepter.

C–D and the section A–B make the construction clear. The dam below this intercepter connection will be 12 inches high. With the exception of the dam, the construction was made when the Fourteenth Street sewer was built, some three years ago, and was filled up with stone and a covering of cement. When the intercepter now under construction is brought to this point, the stone will be taken out and the dam built. Fig. 8 gives a section of the lower end of the sewer, with location and method of junction with manhole.

Fig. 9 shows a common form of the proposed improved cross-section of Pogue's Run. The bed of the run is to be depressed from three to five feet; walls are to be built for banks, where not already in proper place; the clear width is to be made uniform, 41, 40, 38 or 36 feet, as

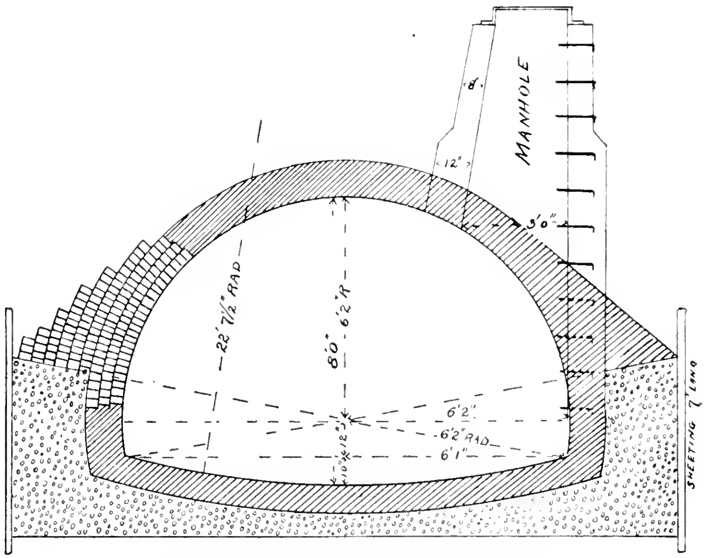


FIG. 8.—FOURTEENTH STREET SEWER.
Section of 8′ 0″ x 12′ 4″ Sewer. Scale, $\frac{3}{16}$ inch = 1 foot.

required; the bed is to be given a slope towards the center and is to be paved; and, as shown, a stone channel, large enough to carry the low water flow in the stream, is to be constructed in the center. Bridges and such buildings and railroad tracks as may be constructed over the

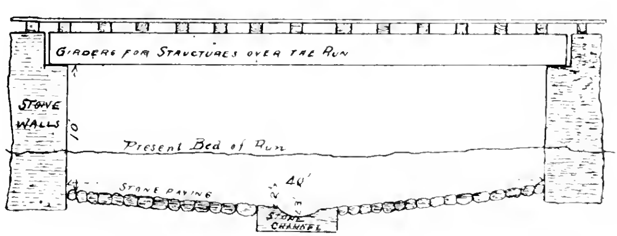


FIG. 9.—PROPOSED IMPROVED CHANNEL OF POGUE'S RUN.
Scale, 1 inch = 16 feet.

run will be supported on girders such as are shown. At present the depth of the run is insufficient in some places, and the channel is crooked and uneven in width, so that eddies form and the bed fills up in places at each flood, forming obstructions for the next. There are also numer-

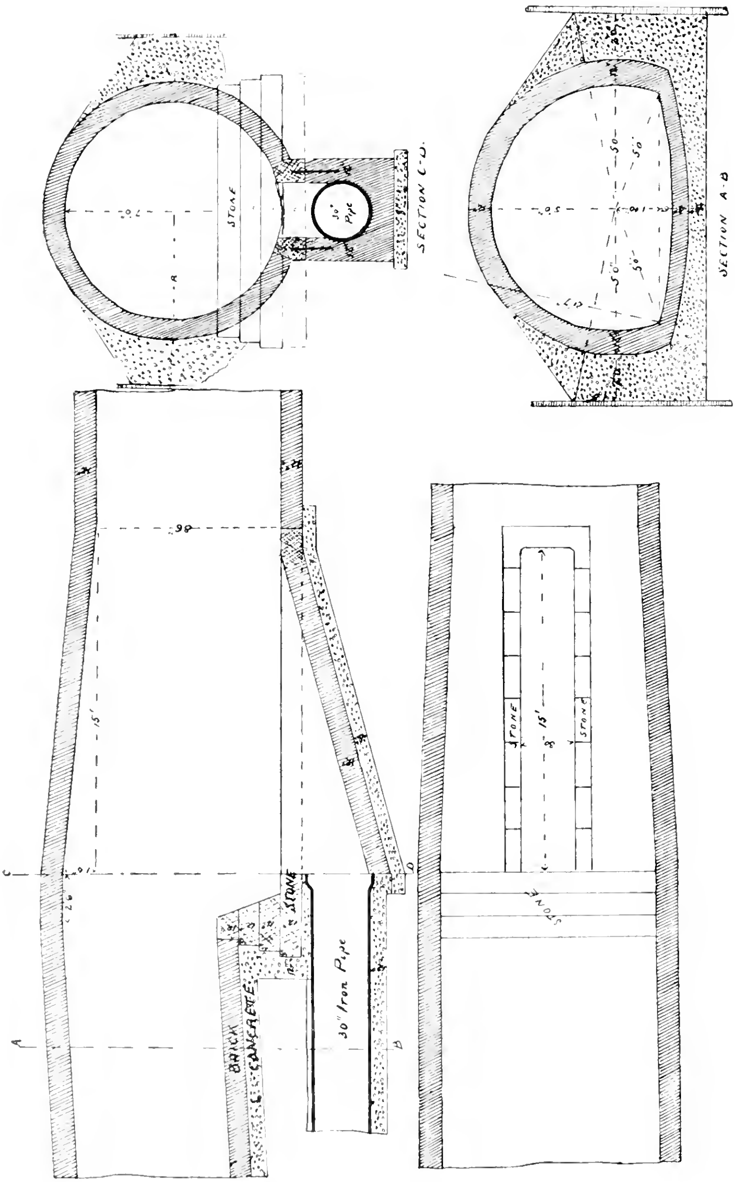


FIG. 10.—MISSISSIPPI STREET SEWER.
Overflow at Pogue's Run. Scale, $\frac{3}{16}$ inch = 1 foot.

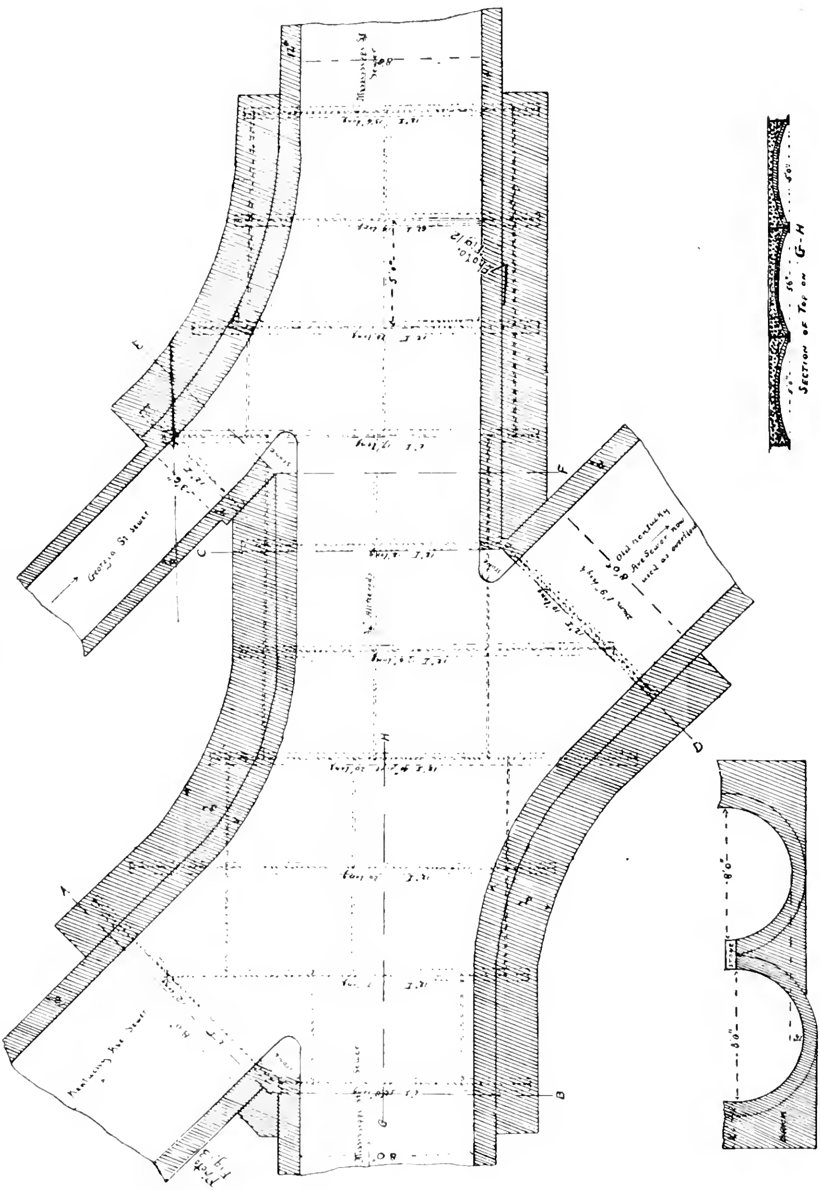
ous obstructions from walls out of line, contracting the width of the channel or interfering with the straight flow of water, and from piers of arches or supporting buildings, all of which serve to make floods in the stream dangerous to life and destructive of property.

Fig. 10 shows the connection of the Mississippi Street main sewer with the main intercepter, and the overflow into Pogue's Run. The drawings show the construction quite clearly. In this case the dam is higher than usual, rather to keep the water of Pogue's Run from going back into the sewer than to turn the sewage into the intercepter. With a channel in the bottom 15 feet long and deepening, as shown on the plans, no dam is necessary to turn the sewage into the intercepter, as all the sewage gets into the sinking channel within a few feet of its beginning. Such a channel has also the effect of keeping the pipe connection with the intercepter clear of debris. Anything which lies across the sewer is floated out over the sunken channel and is out of the way, and anything else is straightened out in the channel and carried through the pipe without danger of stopping. When sufficient flood comes to overflow the dam, all floating matter is carried off into the run.

A comparison of the connections with the intercepter at Fourteenth Street, at Indiana Avenue, and at Mississippi Street, will show the three forms that have been used. Other connections are of about the same form as that at Indiana Avenue. The experience with these latter connections is that they are easily obstructed by sticks, which collect smaller refuse until the sewage overflows the dam and runs into the stream near by. This calls attention to the stoppage and calls for its removal. The Mississippi Street connection, on the other hand, keeps itself clean and has never been seen with any refuse lodged about it. The Fourteenth Street connection has not yet been put into use, but it may be presumed that it will be liable to similar stoppages to the first ones mentioned, though not so frequently, on account of the size of the connecting pipe.

Figs. 10 and 11 show also the intersection of the new Mississippi Street sewer with the old Kentucky Avenue sewer. Both are 8 feet in diameter above the junction, and the Mississippi Street sewer is 8 feet and 6 inches below the junction. The smaller Georgia Street sewer comes in on one side. The principal feature of the design is the roof. Instead of the customary arch, which would be of unusual dimensions and require a large amount of material to make it sufficiently strong, it is made of 12-inch I-beams, weighing 40 pounds to the foot, set 5 feet apart, with brick arches between, the whole being covered with 12 inches of concrete. The arches are kept from spreading by $\frac{3}{4}$-inch tie rods, as shown on plan. It was the intention to protect the iron with tile, where not covered by the brickwork of the arches, in a manner similar to that used in building construction, but the roof was finally built as shown

Scale, 1 inch = 9 feet.



Section of Bottom on A-B
Scale, 1 inch = 12 feet.

Section of Top on G-H
Scale, 1 inch = 9 feet.

Fig. 11.—Mississippi Street Sewer.
Intersection with Kentucky Avenue Sewer.

without this covering, the beams being thoroughly covered with three coats of asphalt paint put on hot before and after lowering into the trench and after being put in place. A special manhole is built just outside the area shown in the drawing to permit of inspection and measurements. The location of the photographs, Figs. 12 and 13, are shown on Fig. 11.

Figs. 12 and 13 were taken just before the roof was put on. They show the beams across the branch sewers, which carry the roof beams at

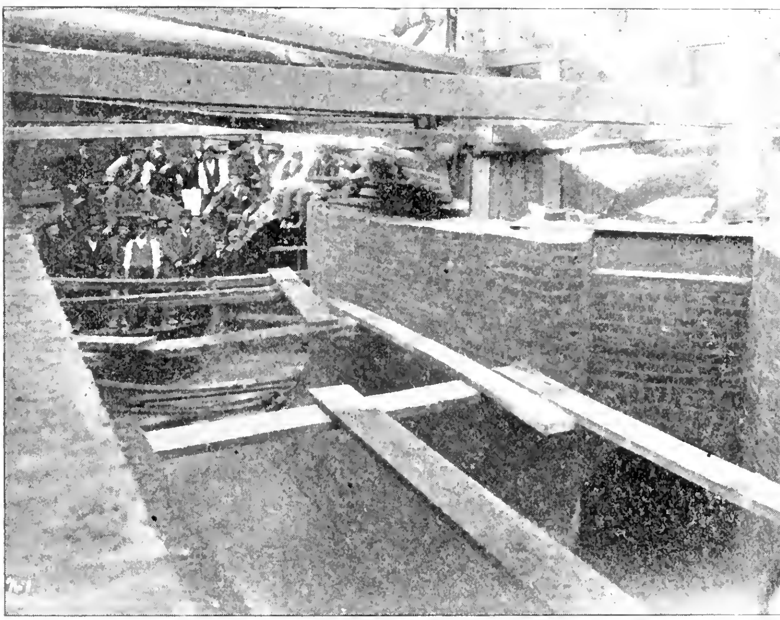


FIG. 12—MISSISSIPPI STREET SEWER.
Intersection with Kentucky Avenue Sewer.

those points; and Fig. 13 shows one of the main roof beams in process of setting.

I quote the following from Mr. E. Hill, the inspector in charge of the work, regarding the experience with water during the construction. Both the Georgia Street and Kentucky Avenue sewers were in use, and the sewage must be taken care of during construction of the junction.

"The upper section of the Mississippi Street sewer, having been given a temporary connection with the Kentucky Avenue sewer, the top of the Georgia Street sewer, which crossed the main ditch, was taken off and a bulkhead built in it at the east side of Mississippi Street.

Another was built in it on the west side of Illinois Street (the next street east and above), turning all water from Illinois and east Georgia Streets down the Illinois Street sewer, leaving only the water that accumulated between Illinois and Mississippi Streets to be taken care of, which was kept in the sewer until the invert was completed. The part of the sewer across the ditch was then taken out and the junction constructed on a curve, as shown on the plan. When the work had progressed far enough past the junction, the bulkheads were taken out and the water from Georgia Street sewer was allowed to pass down the new sewer. In

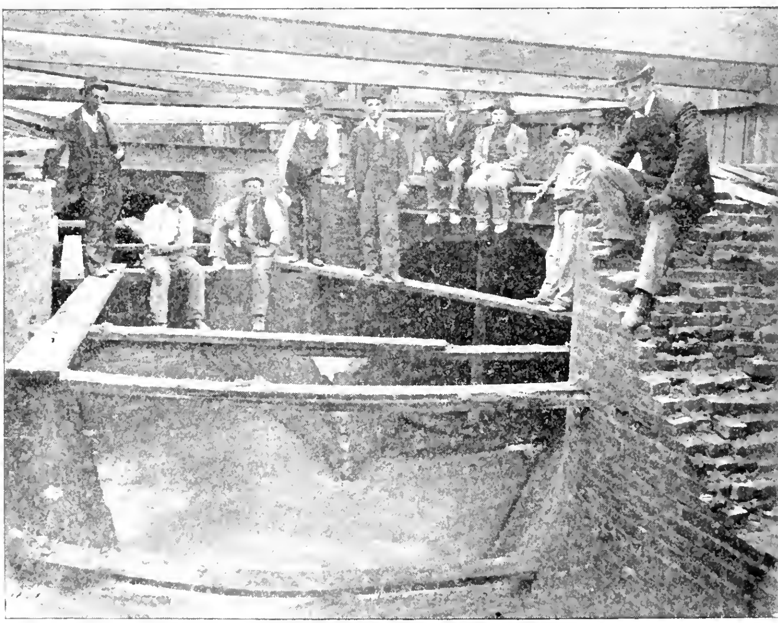


Fig. 13.—Mississippi Street Sewer.
Intersection with Kentucky Avenue Sewer.

meantime the work of tearing off the top of the old Kentucky Avenue sewer, and the placing of a wrought-iron pipe between bulkheads, had been completed. The pipe was 30 inches in diameter and 42 feet long, made in three sections to facilitate handling. Twenty-six feet of it had been an old boiler and 16 feet was new, made for the purpose, of ¼ inch plate. The whole was bolted together. The pipe was firmly bedded in the bulkheads. To prevent removal by the water in case of flood, the bulkhead on the east side was 6 feet thick and thoroughly cemented together. It was at this stage of the work that we were visited by a heavy

storm that had been threatening for three days. The invert of the Mississippi Street sewer was in just past the Georgia Street sewer and up to the Kentucky Avenue sewer on the west side, and the side walls were about half way up when the storm came. The upper part of the Mississippi Street sewer had been constructed, but was not yet in use. However, some water did reach it. There was a temporary bulkhead in it at its lower end (the upper end of the excavation for the junction), which burst, and the accumulated water washed out a part of the sheeting across the end. Georgia Street sewer ran full at Illinois Street, but the 30 inch pipe stood its ground and carried off all the water coming down the Kentucky Avenue sewer. I account for this by the water backing up, and the capacity of the sewer being such as to hold it until the flood subsided. One and seven-tenths inches of rain fell in fifteen hours, and one inch of it fell in one hour. Outside of washing into the sewer a large quantity of sand, the damage was slight. The work was delayed a few hours, and the first thing done was to repair the broken bulkhead and put in another one at Mississippi and Washington Streets, and make a connection with the Washington Street sewer to turn the water from the upper section of the Mississippi Street sewer west, until the work was completed. The work of completing the inverts of the Mississippi Street and Kentucky Avenue sewers was then proceeded with and was no mean task. The angles and curves were laid off according to plan, and in order to insure true curves in the brickwork, I had curves made out of wood and placed in proper position for the masons' guidance. You will readily see that the whole of the invert was simply a series of groined arches upside down and strengthened by placing them in solid brickwork, as the outside of the side walls was carried down vertically to the bottom of the invert, the walls being 3 feet wide at the top. A dam was constructed on the west side of Mississippi Street, in the lower section of the Kentucky Avenue sewer, 1 foot 9 inches high. This will make a total height above the bottom of the Mississippi Street sewer of 2 feet 4 inches, so that the water must get above this dam before it can go down the Kentucky Avenue sewer to the river, which sewer was the original outlet for nearly all the sewage of the city."

The method of carrying through an improvement and collecting the payment for it is as follows:

The Board of Public Works orders the City Engineer to prepare plans for the sewer desired. This order may be given with or without petition of property owners interested or to be affected.

The City Engineer prepares the plans and specifications, including therein full directions as to manner of doing the work and a statement of the entire amount of work to be done, with full detail drawings showing location of sewer and all appurtenances and connections and specifications of kind and quality of materials required. The total length of

the sewer to be paid for is specifically stated, and the line is described. All branches or connections not given in the description of the line are appurtenances and not considered in measuring up the length of sewer constructed.

Should the sewer be a local sewer, intended to serve only the property abutting on it, a resolution is prepared, stating that the Board considers it necessary to construct a local sewer on the described route under the accompanying plans and specifications, to be paid for by the abutting property. Should the sewer be a "main" sewer, intended to serve not only the abutting property but also as an outlet for branch sewers, the City Engineer estimates the cost of the sewer as designed and the cost of a sufficient local sewer on the same line, and thus determines the percentage of the total cost which is properly chargeable to the abutting property. This percentage is stated in the resolution, which differs from the local sewer resolution also in describing the district over which the remainder of the assessment is to be distributed, and containing a map of the district. In the resolution any liability of the city for any part of the cost other than as any other property owner, is specifically disclaimed, and the areas of streets and alleys are not included in the total area of the district to be assessed. This resolution is passed as a declaratory resolution, and a day for hearing remonstrances from persons interested in or affected thereby is set and advertised once each week for two weeks. On the date set the Board takes final action, confirming, modifying or rescinding the original resolution, and such action is final and conclusive on all persons.

If the resolution is confirmed or modified, notice of a day for receiving bids for constructing the work according to the final form of the resolution is published once each week for two weeks, such day being at any time not earlier than ter days after the first publication of advertisement for bids. On the day set, the bids are received and opened and the contract may be awarded. The custom has been to award the contract to the lowest bidder and to reject all bids if the lowest bidder were not a satisfactory person. Sometimes, when the difference between the lowest bidder and the next was not too great, the contract has been awarded to the next lowest. The Board reserves the right to reject any or all bids. In the case of street improvements, the lowest bid is frequently rejected if the material proposed to be used is not satisfactory, but this is not necessary in the case of sewers, as all bidders will use practically the same kind and quality of material. (It will be noted that it is not possible for a sewer to be stopped by remonstrance if the Board deems it necessary to pass the resolution.) The contractor files with his bid a certified check of amount stated in the advertisement, which is returned to him if his bid is not accepted, or, if his bid is accepted, when he has filed his bond of 50 per cent. of the cost of the work, for construction and maintenance

of the work according to specifications. The bond covers the construction of the sewer and its maintenance in good condition and repair for a period of three years from the date of its completion.

When the bond is accepted and the contract signed by the Board and by the contractor, the contractor begins work within the time limit set by the contract and completes it within the time limit set, under penalty of $50 a day for delay, unless the date of completion is extended by resolution of the Board. The bid states the price per lineal foot at which the sewer will be constructed, and is practically obtained by the contractor by computing the entire cost of the sewer with all its appurtenances, and dividing this cost by the length of the sewer proper. given in the specifications. According to the strict letter of the charter provision, the assessment roll would be made up with this contract price and length, but, practically, the sewer may differ somewhat in length from the specified length, and so the completion of the assessment rolls is delayed until the sewer is completed, when the City Engineer measures its length and reports to the Board of Public Works the total cost of the sewer, which is this length, multiplied by the contract price per lineal foot, less deductions for appurtenances or connections or other work not constructed, and plus such extra work as has been agreed upon by the Board and done by the contractor. There is no definite provision in the charter for these deductions and additions, but there are numerous decisions by the Courts justifying them, and others which would show that, even if they do not come under the decisions mentioned, the assessments against property would only be successfully attacked so far as the few cents due to the extras are concerned.

The assessment roll is then prepared by the assessment bureau. In the case of a local sewer, the assessment is made by dividing the total cost by the area of the abutting lots in square feet, with special provisions limiting the depth to 200 feet in case of unplatted ground not already assessed for sewer on one side, or to 50 feet in case such ground already has a sewer on one side intersecting the side on the new sewer. The assessment against each piece of property is then determined by multiplying the area of the lot by the cost per square foot. In the case of a main sewer, the amount of local assessment is determined from the total cost and the percentage thereof to be assessed locally, stated in the resolution, and the local assessment on each piece of abutting property is obtained as above. The total area of the property in the district, and the amount of the district assessment remaining after deduction of the local assessment, is then determined. The district assessment on each piece of property is then obtained in a similar manner. This is the total assessment on property not on the line of the sewer. Abutting property pays the sum of the local and district assessments. All of the large main sewers for the city, with the exception of

some outlying districts, have been paid or contracted for under this system, so that it would probably be unjust to modify the system now ; but the system in use in the State outside of Indianapolis is better in one way, in that it permits the city to assume the payment of a portion of the cost of a sewer in case it is used for other than local sewerage, or is an outlet or intercepter of value to the city at large and of very little value to the abutting property along the lower end of its route. The city of Indianapolis, by the Common Council, did, however, pay a portion of the assessments against such property as that last described along the lower end of the main intercepter after the assessment had been made, and it was shown that the assessments operated to confiscate the property. There is, however, but the one instance of this.

When the assessment roll is completed, it is approved by the Board of Public Works and sent to the City Controller; he forwards a certified copy to the City Treasurer. The contractor must, within ten days, send to each property owner, notice of the approval of the assessment roll by the Board of Public Works. For thirty days after the approval of the roll, the owners of property assessed have the privilege of paying in cash or of electing to pay in ten annual instalments. In the latter case they must waive any objection as to legality or regularity of procedure. The deferred payments draw interest at the rate of 6 per cent., payable semi-annually. Coupon bonds, which are a direct lien upon the property assessed, are issued for these deferred payments. If the property owner fails to pay in thirty days, or at date of any semi-annual payment, the entire amount becomes due and can be collected by the contractor or by the holder of the bond, the city having no liability and no duty in the matter.

The fact that there are no partial estimates and no payments by the city, and that, therefore, the contractor must carry the work until thirty days after final completion and acceptance, operates to shut out small contractors and irresponsible persons from bidding on work of any magnitude, and as a consequence the character of contractors is above the average. The fact that each bond is for the sum due from a special piece of property, and is a special lien on it, makes the bonds of odd amounts. This, and the fact that one-tenth of the principal is payable each year, causes the bonds to be at a slight discount (2 to 4 per cent.), and increases the cost of work by so much. It would be possible for the city to issue the bonds for uniform amounts and times, and form a sinking fund from the annual payments to take them up when due; but so far that has not been done. Interest on the money invested in the contract also operates to increase the price bid. Notwithstanding all this, the work of the last two years has been done at an average price for good work considerably below that elsewhere with which I am acquainted.

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RECENT IMPROVEMENTS IN COAL-HANDLING MACHINERY.

BY JOHN D. ISAACS, MEMBER OF THE TECHNICAL SOCIETY OF THE PACIFIC COAST.

[Read before the Society, February 7, 1896.*]

THE purpose of this paper is to describe certain improved apparatus for handling coal, recently constructed by the Maintenance of Way Department of the Southern Pacific Company, and applied to the receiving bunkers at Port Costa and Oakland Wharf, and to the distributing bunkers at San Luis Obispo, West Oakland and Rocklin.

Our conditions of operation require that most of our coal should be landed from ships into receiving bunkers, and transported thence by rail to the various points of consumption, at which points the coal must be placed upon the tenders of locomotives. The high cost of coal delivered at the wharf, the high rate of wages paid stevedores on this coast, and the importance of quick dispatch for colliers, indicate three directions in which it is desirable to economize:

(1) In diminishing as far as possible waste and breakage.

(2) In dispensing with manual labor in discharging and distributing.

(3) And much the most important, dispatch in discharging ships.

Of these, the need of the first and second is self-evident. As to

* Manuscript received April 1, 1896.—*Secretary, Ass'n of Eng. Socs.*

the third: It must be remembered that our colliers have an earning capacity in only one direction, that somewhat less than one-half their time is devoted to their actual business of coal transportation, and that therefore any means of diminishing their idle time is important.

An ideal system of landing coal from vessels would be some form of mechanical conveyor, delivering coal from the hull of a ship directly into the receiving bunker, digging its way into the coal until bottom is reached. This would be supplemented with a fore-and-aft conveyor, in the ship, bringing the coal to the main conveyor. Such systems are in use in the Eastern and Middle States for unloading barges.

But, on this coast, the many complications surrounding the problem seem to put this method almost beyond practical possibility. Some of the difficulties are: Variations in sizes of lumps, from dust to pieces a couple of feet in cubature; very wet coal, very dry coal, range of tides, variations in the draft of ships, and in the size and position of their hatches, the interference of ships' rigging, special construction of ships as to bulkheads, etc., etc.

Under these conditions there seems to be, at present writing, but one practical way of attacking the problem; that is, with a hoist or derrick, lifting a bucket which contains the coal. It is towards improving this method that our attention has been principally directed.

Although the ordinary tipper bucket is well known to you, it may not be out of place to remind you briefly of the principle of its construction and the mode of its operation, in order to bring out strongly the contrast between it and later forms now in use.

The tipper is constructed on the principle of an ordinary water bucket. It has a bail, and is so dimensioned that when it is empty the center of gravity of the bucket is below the trunions. When the bucket is filled the center of gravity is above the trunions and slightly to one side of the vertical through them.

The bucket is held in place by a catch. The tipper is provided with wheels. The mode of use is as follows: The empty bucket is dropped into the hold of the ship, disconnected from the hoisting line, pushed on planks to one side, filled by shoveling, trundled back, connected up and hoisted. It is swung over the bunker, and run up to the end of the derrick boom. At this point the catch is released by suitable mechanism, and the coal is thus dumped.

All this involves much manual labor and a high dump for the coal. To obviate these objections many varieties of dredger buckets have been devised. On this coast they are euphoniously called "grab buckets." They all work on the principle of the clam-shell dredger; *i. e.*, they dig their way toward the keel of the ship; the coal constantly tumbles into the inverted cone made in excavating, until, when the bottom floor is

reached, there remains only a portion of the coal, which has to be trimmed—that is, shoveled to the bucket.

The requirements for this kind of bucket are:

It must be simple in construction, having few parts and those easily replaced.

It must require no nice adjustment, and have no delicate mechanism.

It must not get out of order in working, and must be able to stand very rough usage.

Its cost must be moderate, and its repair account low.

It must be so geared as to "bite" lumps of coal in two when they are caught between the edges of the wings.

It must be so arranged as to bury itself well into the coal, so as to come up full.

It must work in any kind or condition of coal.

It must have a low dump; that is, it must be capable of delivering the coal on the pile with as little fall as may be desired.

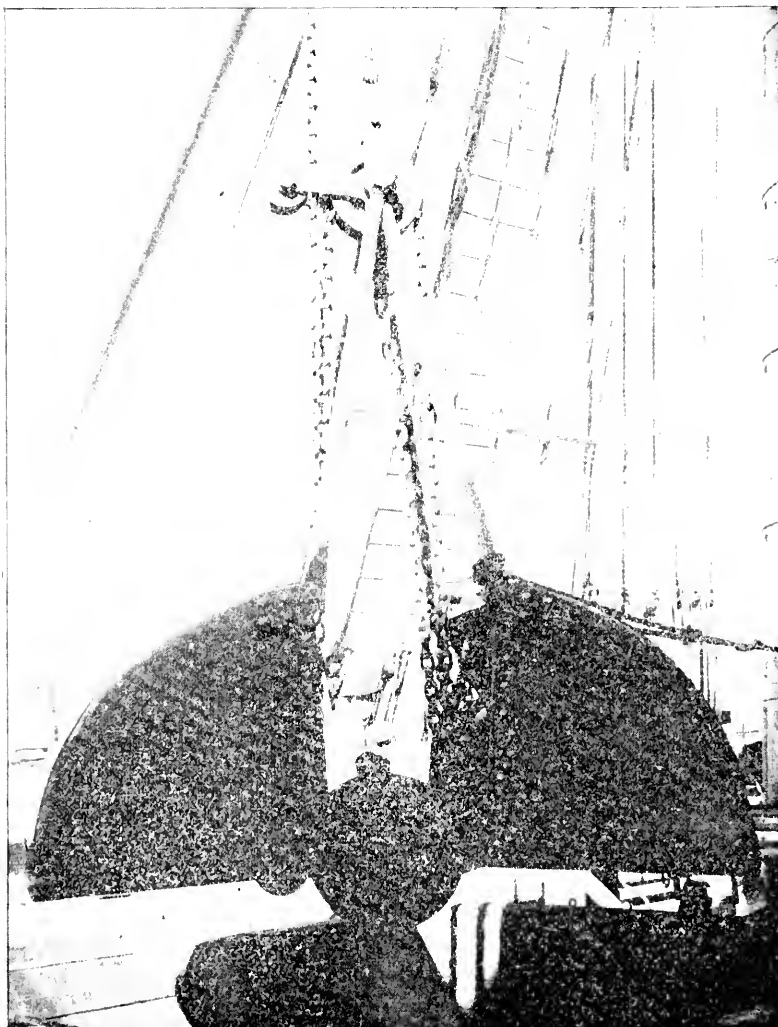
It must be handled entirely by the derrick engineer, and be certain in action.

Of the various forms of buckets of the grab type brought to our notice, none seemed to us to fill all these desirable conditions. Those which conformed to the most essential—automatic action, low dump and applicability to various conditions of coal—proved to be very complicated. One of the best in operation is such a collection of gears, catches, springs, pawls, etc., that constant delay and expensive repairs seem necessarily to accompany its use.

The bucket is operated as follows: It is lowered into the hold, both lines being paid out together. When the bucket has nearly reached the coal, the running line is let go. The weight of the lower sheaves, hinges, etc., throws the bucket wide open by the time it reaches and rests upon the coal. The hanging line is now let go and the running line hauled in. The bucket buries itself in the coal up to the lower sheave shaft, and closes. Both lines are now run in together, but the lift is kept entirely on the runner. As soon as the bucket clears the hatch, swinging begins. The bucket just clears the top of the bunker, and no further hoisting takes place, but swinging continues up to the point of discharge. Here the hanging line is held and the runner released. The bucket opens promptly, and the coal is dumped. By this time a reverse motion towards the ship has begun.

Occasionally, in discharging, we come upon a layer of large lumps, which has much the appearance of a paving of coal, over which the bucket would slide without filling. A stevedore loosens this with a few blows of a pickaxe, while the bucket is up, after which there is no further difficulty.

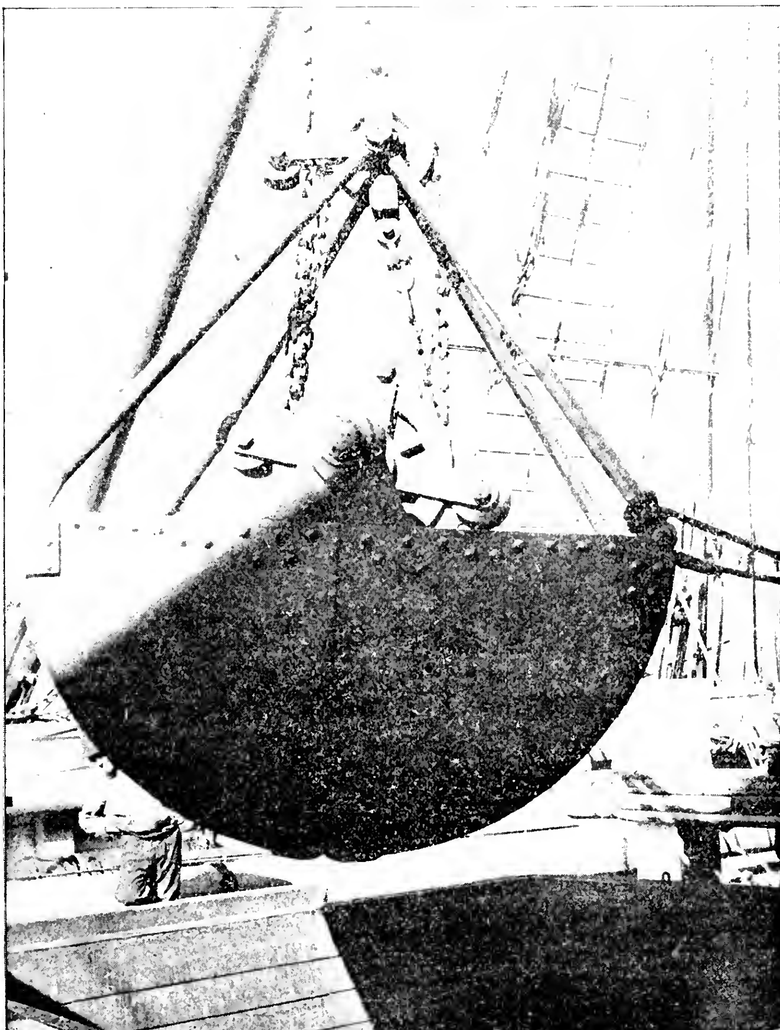
If the coal is very soft and friable, the bucket may be lowered to the coal pile before emptying, giving no appreciable fall to the coal. With ordinary coals this precaution is not necessary.



Grab Bucket Open.

It will be noticed that the center K of the pivot shaft is above the center with which the wings are struck. This gives a scooping motion to the bucket when closing, causing it to bury itself well into the coal.

The tipper bucket is limited in size and weight, by the fact that it must be trundled around in the ship. Buckets of this kind, used by us,

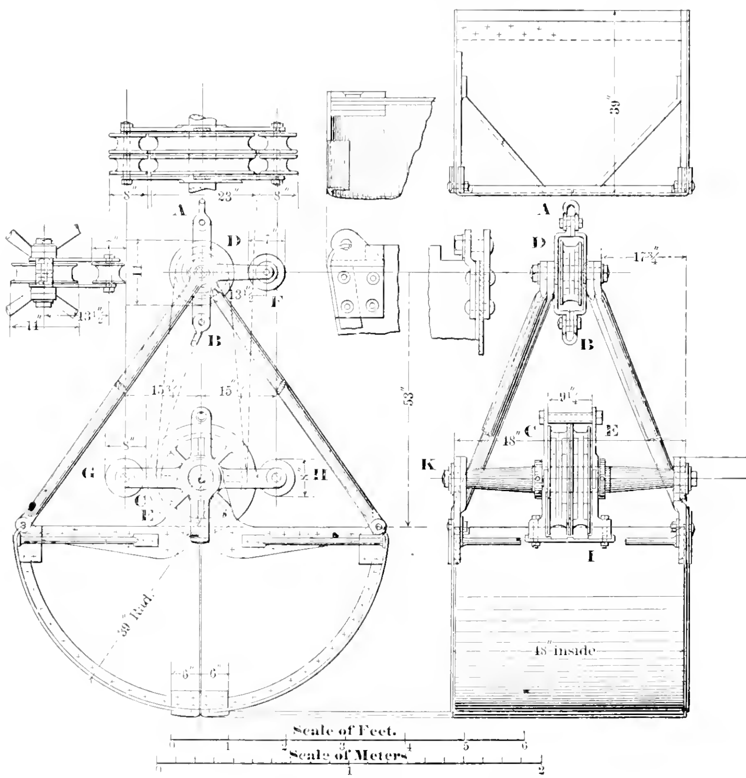


GRAB BUCKET CLOSED.

weigh 1,400 pounds each, and have a capacity of 700 pounds of coal, or a ratio of dead weight to useful load of two to one.

The grab bucket is limited in size only by the dimensions of the hatches and the capacity of the derrick. We have three sizes, with

capacities, level full, of 3,000, 3,800 and 5,000 pounds respectively. Of these, the second (3,800 pounds) seems to be about right for our conditions, and is now the only kind in use. Its weight is 3,775 pounds, giving a ratio of dead weight to useful load of one to one. The maximum speed of lift of each is about 400 feet per minute. The average fall of coal from the tipper bucket is 21 feet; from the grab bucket, 8 feet. The number of stevedores per hatch for tipper bucket,



Coal Bucket for Oakland Wharf.

Capacity, 64.4 cubic feet = about 3,800 lbs. Carbon Hill Coal at 59 lbs. per cubic foot level full. Weight of bucket, 3,775 lbs.

is six; for the grab bucket, one, until bottom is reached. Each kind of bucket requires a signal man at each hatch, whose duty it is to notify the engineer by bell code how to handle the bucket while it is in the hold. We usually keep a man at each hatch, when the coal has been excavated nearly to the bottom of the hold, to steer the bucket with a guy line, clear of lower deck beams, etc.

In view of these statements it requires no further particulars to

show a considerable gain in time in handling coal by the use of the grab bucket shown, and consequently greater dispatch in unloading our colliers.

Five of these grab buckets have been in almost constant use at Oakland Wharf since November, 1894. None of them have delayed work one moment by disarrangement, and, so far, they have no charges against them for repairs.

The derricks handling these buckets are of ordinary type, with double independent drums, friction brakes and the usual appliances for such machines. They have a reach of 32 feet, and are flexibly connected with a steam pipe between derrick tracks. The track gauge is 8 feet. The derricks are hooked down the track stringers when in use. The following are their principal dimensions:

Two cylinders 11 inches x 12 inches.

Two drums 36 inches diameter x 18 inches long, spirally grooved.

Tops of rail to center of boom sheaves, 18 feet 6 inches.

The engines are not reversible, as all lowering is done with brakes. The derricks may be disconnected and run to any point on bunker to suit ship hatches.

Steam is supplied from a suitable boiler at the end of the bunker through a continuous pipe laid between the derrick tracks.

The receiving bunker is in all respects, except that it has no inclined trestle approach, the same as the local distributing bunker which, with certain improved details applicable to both, will presently be described.

The next step is the transportation by rail from the receiving to the distributing bunker.

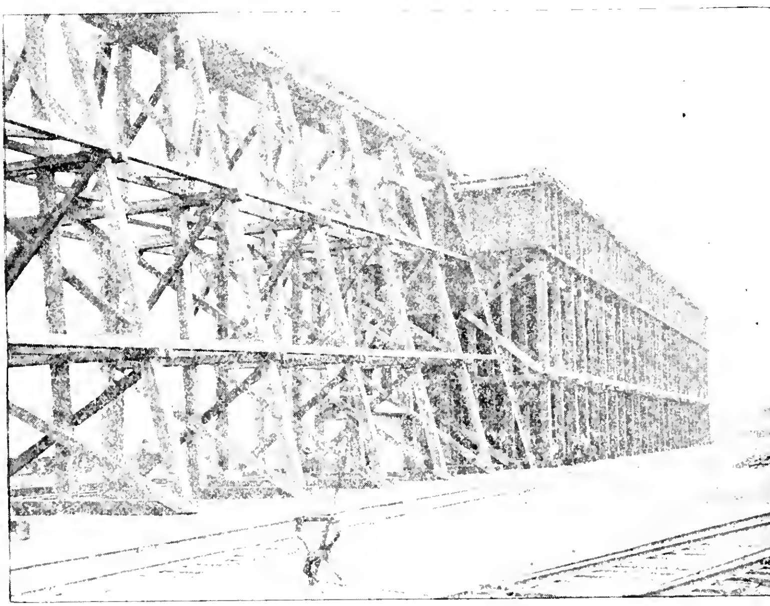
Coal cars are run on a track under one side of the receiving bunker. The cars are then filled, being moved slowly under the chutes to load them uniformly, and then hauled by locomotives to the distributing bunker.

The distributing bunker consists of a wooden framework, heavily built and well braced, as shown. At one end is an inclined trestle having a grade of 5 per cent. In order to enable the coaling tracks to pass under the bunker the first seven trestle bents next to the bunker are built unsymmetrically, but stability is maintained by horizontal bracing, which anchors the narrow bents to the bunker at one end and to the broader bents at the other. The bunkers have a capacity of 10 tons per foot run, level full. They contain an average of 1,266 feet board measure per foot run, and cost, by contract, about $36.60 per foot. The trestle approach contains an average of 266 feet board measure, and costs $6.60 per foot run. The track on top of bunker is 46 feet above the coaling track.

When the first of these bunkers—that at San Luis Obispo—was built, there was some discussion as to whether it was better to run the coaling tracks under the bunker or outside. The plan was adopted because it takes up the least yard room, and because (as it is desirable to be able to empty the bunker from some one track) this form gives the greatest capacity for a given height and width.

On the coaling track there is a track scale just before the bunker is reached.

On arrival of the loaded cars in the yard, a switch engine is coupled to them, taking from two to four at a time. The engine

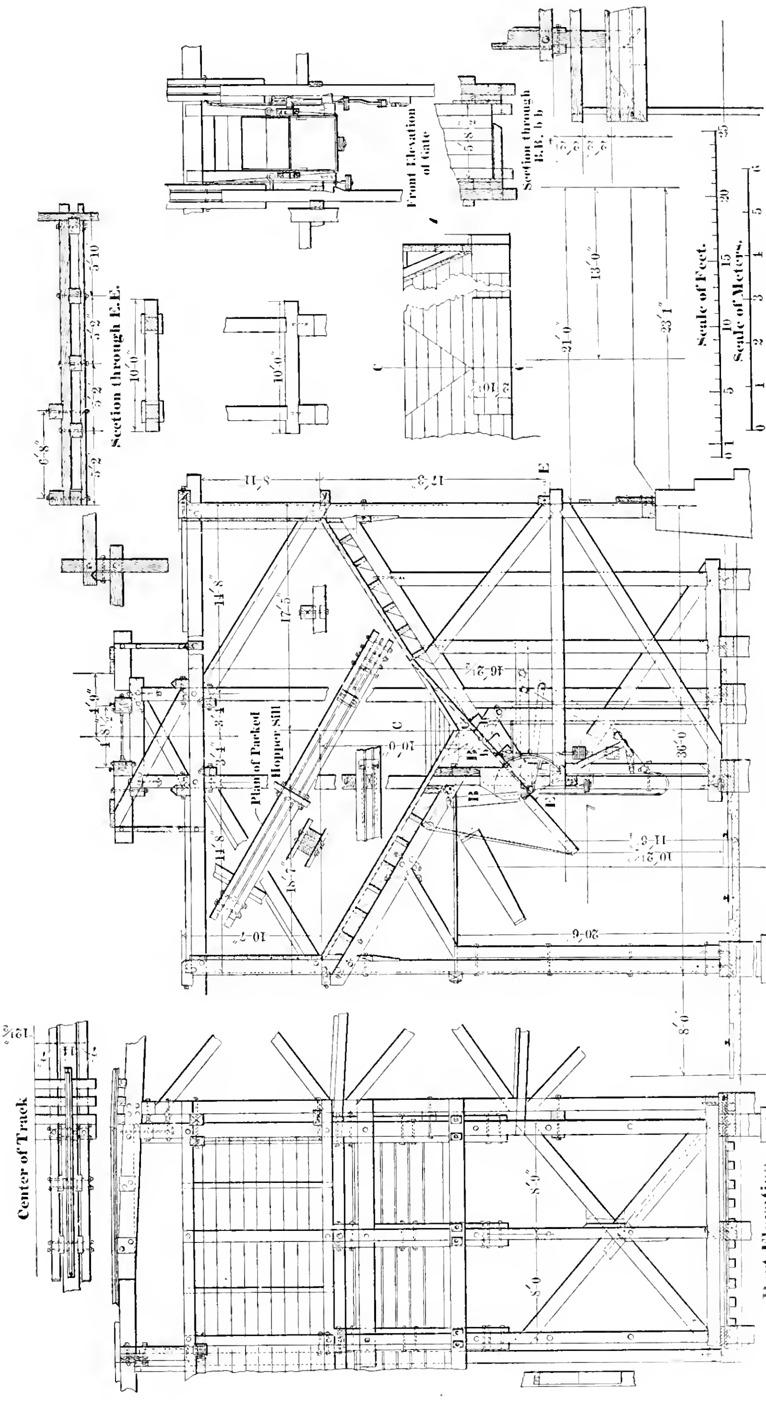


Oakland Distributing Bunker.

approaches the trestle on a run, and pushes the loaded cars ahead to the top of the bunker. Here the cars are, at present, unloaded by shoveling, but hopper-bottom cars are intended to be used. The shoveling here does not amount to very much. Most of the coal is simply pushed overboard.

At the further end of the bunker there is a heavily constructed buffer, to prevent accidental overrunning.

Engines to be coaled are run over the scales, and the tender is weighed and registered. The engine then runs under the bunker. The chute is lowered, the gate opened, the tender filled, backed to the scales



COAL BUNKER, SAN LUIS OBISPO YARD.

and weighed, and the amount of coal is registered. A duplicate tag is given to the crew, showing coal received by them. The work done with this coal forms a part of the engineer's and fireman's record.

Previously to the fall of 1894, when the distributing bunkers at San Luis Obispo were built, the operation of the gates through which the coal is delivered was a source of constant complaint. The gates were of the ordinary upward sliding kind, worked with levers. They were made of boiler plate, had angle iron frames, and were provided with a cutting edge at bottom to enable them to be closed through the stream of coal. Frequently—in fact usually—closing was prevented by a lump of coal or of slate. A pinch bar was then driven into the wood over the gate, and the cutting-edge forced down. The woodwork was badly torn up by this, and coal frequently overran the cars, sometimes burying them before it could be stopped. Sometimes this could be obviated by partially raising the chute until the coal was brought to rest, then digging out the impeding chunk, forcing the gate down, emptying the chute and pulling it up again, before the train could pull out.

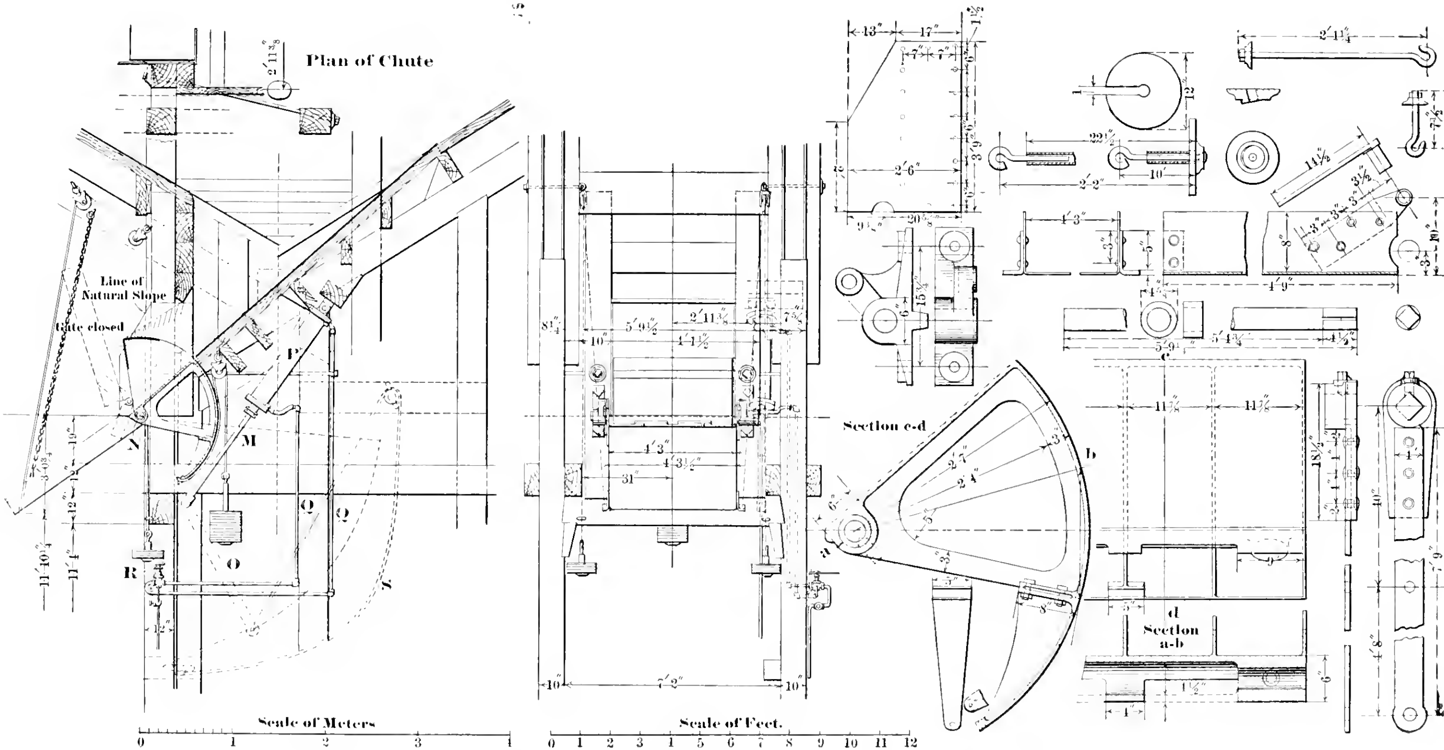
In the Port Los Angeles bunker we put a cast-iron rack behind the gate to give a purchase for the pinch bar. This saved the woodwork, but the other troubles remained.

A consideration of these difficulties led to the development of our gate and chute. The principle is simple and obvious. It amounts to placing, beyond and away from the opening of discharge, a removable retaining wall, which, when closed, rises to the line of natural slope of the top of the coal, and, when open, falls to the level of the floor of the chute of which it then forms a part. In closing, large lumps either stop behind it, or roll over it.

Having decided upon the principle to be employed, several methods of application were considered. The most obvious was to push a flat gate up through the coal until the line of repose was reached. This involved stiff construction, rollers, guides and other complications. These considerations brought us to the rotary gate, of which there may be two forms, one having its pivot next to the bunker, and the other, as adopted, having its pivot away from the bunker. Our reasons for preferring the latter are, that in closing its motion is in the same direction as that of the coal, so that the momentum of the stream is stopped gradually, and when open the back can be made to form part of the chute. Besides, the details seemed to be simpler.

When the first of these was made, it was so constructed that the bottom of the hinged chute, when up, closed against the upper edge of the gate. This was to avoid the splash when commencing to fill an empty bunker. Experience has shown this to be unnecessary.

The gate *M* is pivoted at *N*, and the gate is actuated by the hand



ARRANGEMENT AND DETAILS OF COAL-VALVE AND CHUTE.

lever *O*. The gate is of cast iron and has no finish except where bored for the pivot shaft. It and the lever are counter-weighted so that it always tends to remain closed except when wide open. It is then on a balance.

As a further convenience for prompt operation, and where we have a compressed air installation for working our signal systems, there is coupled to the lever *O* a small air cylinder *P*, oscillating on a pivot at one end, supplied by the pipes *Q* and manipulated by the four-way cock *R*. The pipes are fastened to the woodwork, and have hose connections to allow the cylinder to oscillate. In this case the line *S* for working the lever is only precautionary, to provide for failure of the air. This arrangement is adapted for Oakland and Rocklin bunkers. For San Luis Obispo the lever is worked by hand, and the line *S* is run to a place convenient of access to the fireman. We can, if we choose, arrange this last bunker for air by connecting the air cock with the brake hose of the engine, so that each engine, while coaling, will furnish its its own compressed air.

In every case the entire coaling is performed by the fireman.

In case it should be advisable to expedite coaling by having more tracks under the bunker, the seven bents of the trestle next to the bunker will be dispensed with and an overhead bridge substituted for them, so that a coaling track may be run on each side of the center. This will leave sufficient space in the center, between tracks, for efficient bracing.

To summarize: We now discharge a ship quickly and with much less shoveling than formerly; load flat cars for distribution with no shoveling; fill the distributing bunkers with little shoveling (none when our hopper cars are at work); load the engine without the shovel; fill the tender with ease and certainty; minimize breakage and have an accurate account of the coal used, to check against the tonnage and mileage of work done with it.

DISCUSSION.

Mr. Richards.—Mr. Isaacs' paper is very complete. The bucket and its operation are extremely simple. He says the Eastern buckets involve from two to four times as much detail. I have had occasion to observe different styles of grab buckets for forty years past, and I have the principal ones pretty clearly in mind. Certainly none of them are so simple as this one that Mr. Isaacs has described. I think it is very creditable to our engineers on this coast.

Prof. Wing.—Mr. Isaacs, in introducing his paper, said they were warranted in increasing the expense of handling the coal in order to

expedite the unloading of the vessels. The fact seems to be brought out that the ratio of live weight and dead weight is less than in the old form of bucket, the number of men is reduced and the rapidity of operation is increased. I would like to know if he can give us any information as to the relative cost of the two methods. It seems to me the cost must be much less with this style of grab bucket than with the old style of bucket.

Mr. Isaacs.—I said that I thought the company could have afforded, if necessary, to pay more for a quicker dispatch in unloading coal. As a fact, we obtained a more rapid discharge at less cost. The speed of hoist is about the same in both. The dead load with our grab buckets is equal to the useful load, while in the old method the dead load was twice the useful load. Taking into account the diminution of the number of men, I think I can safely say the cost has been reduced one-third.

Mr. Curtis.—I know it is fully that.

Mr. Isaacs.—This grab bucket discharges 3,800 pounds of coal at a single lift, while the old type of bucket discharges 700 pounds, and makes as many trips as the other. The full capacity of the coal bunkers represented on the diagram is ten tons to the foot run. The Oakland bunker is 200 feet long, and has 2,000 tons capacity. The bunkers at San Luis and Rocklin are 300 feet long, and have a capacity of 3,000 tons each. That at Oakland wharf is 400 feet long, and has a capacity of 4,000 tons.

Mr. Isaacs.—The largest of our colliers hold 4,000 tons. The coal bunker at Port Costa is 800 feet long, and holds 8,000 tons, or the cargoes of two colliers. The coal bunker at Port Los Angeles is the same.

Prof. Soule.—Did you notice any considerable reduction in the breakage and powdering of the coal by the use of these buckets?

Mr. Isaacs.—That is a question difficult to answer as to definite amount. We know that we did lose a good deal by breakage, and that we have obviated much of the loss by having a lower drop for the coal.

Prof. Soule.—It was a question with me whether the driving action of the bucket into the coal would not tend to grind the coal more than shoveling it into the bucket, as before.

Mr. Isaacs.—Probably it would do so a little, by lumps being broken in two from coming in between the jaws.

PRACTICAL NOTES ON UNDERGROUND ELECTRICAL SERVICE.

By E. J. Spencer, Member of the Engineers' Club of St. Louis.

[Read before the Club, January 22, 1896.*]

It is a fact not generally known—at least I have but once seen it commented upon—that the inventor of the telegraph used underground wires in his first attempt at commercial telegraphic installation. One of the exhibits that we lost for lack of space at the World's Columbian Exposition was a lot of antiquated instruments, a length of cable, and a plow drawn by oxen—the relics now in possession of the Baltimore & Ohio Railroad of the first telegraph—the plow used in opening the trench, the cable laid therein, and Morse's earliest instruments. It was about 1832 that the first section of the proposed telegraph from Baltimore to Washington was laid. The section was five miles in length, extending from Baltimore toward Washington. At great expense Morse and his supporters had made a leaden tube into which four wires had been drawn. These wires had been insulated by a wrapping of cotton which was painted with shellac. Through this cable the futile effort was made to operate the Morse telegraph. It is reported that Morse himself was discouraged and dismayed at the outlook, when one of his associates suggested that they put their wires in the air. This was done, and the system worked. Thereafter, all effort at underground service ceased, and the search for an insulated cable was limited to means for crossing rivers, etc.

Upon completion of the Philadelphia and New York line in 1845, an effort was made to convey the messages directly to New York City by wire under the Hudson River. This was a failure, however, and for some time the messages were conveyed by boats. In 1842 a copper wire, wrapped with hemp string, and coated with india-rubber and pitch, was laid from Governor's Island to the Battery in New York, but refused to work. In 1846 a similar arrangement was encased in a lead pipe, and laid across this channel, but also refused to work. The probability is that in none of these cases was the rubber vulcanized, as it was about this time that Goodyear made his great discovery, giving to rubber a value in the arts that it never could have attained in its raw state. Gutta-percha was introduced in 1847.

Experience abroad was much the same as that of Morse. In St. Petersburg Jacoby used cotton-covered wires sealed with rosin into a leaden pipe. But the insulation cracked and the cable broke down.

* Manuscript received April 18, 1896.—*Secretary, Ass'n of Eng. Socs.*

Rubber and gutta-percha were recognized as the only insulators with the prime physical requisite, viz.: that of flexibility; but in earlier days of limited facilities of transportation, rubber and gutta-percha were too expensive for use, except in case of submarine cables.

In 1856 began the commercial production of paraffine, which quickly assumed an importance in the manufacture of electrical apparatus, house wires, etc. By this time the use of aerial wires on poles, with glass insulators, had proven so satisfactory that there was no demand for underground cables for telegraphic purposes. One enthusiastic individual broadly patented the use of paraffine and its oils as insulation. Many years afterward, in the early days of electric lighting, he displayed wires, cotton covered, led through tubes in which oil was forced to circulate. The insulating power of the oil was remarkable. If a break occurred at any point in the insulation, the oil quickly closed upon it, reproducing the insulation as good as ever. The exhibit was sufficiently attractive to enlist considerable capital, and a commercial system of lighting was, I believe, actually installed after this model. The evident objection of uncleanliness, and the many physical difficulties encountered in such a system, caused its abandonment. Oil is now used in a limited way in the insulation of transformers, and other stationary apparatus, under a very high electrical pressure.

The first Atlantic cable was partly laid in 1856, and the first cable was completed in 1858, but the service was never satisfactory; and not till the second cable was laid, in 1866, was the Atlantic cable a commercial success.

In England, probably due to the existing cable factories, telegraph cables were laid underground as early as 1852. These were gutta-percha cables similar in characteristics to the Atlantic cables.

In Berlin a committee of savants had examined carefully into the failure of cables previously manufactured, and had reported that this was due to cracking of the insulation when bending cable in the process of manufacture, or in the course of transporting into place; the ultimate destruction of the cable was apparently just as sure whether these cracks were large or microscopic. The committee recommended—

First: That the insulation be put on in layers concentric with the core, thus permitting a slipping of layers in bending, and the interruption of the continuity of such cracks from copper core to the exterior.

Second: That the insulation be of such viscous character as to act as a solid when forced into these jute or fiber layers, but with sufficient fluidity to run together in case of incipient cracking.

The effect of this recommendation is seen in the construction of the Siemens' cable to-day; and thus early we have abroad the two great classes of cables, the rubber and the impregnated fiber.

There was no incentive in this period to cable-making in the United States. During our civil war many attempts were made to fire submarine mines moored in navigable channels,connected to the shore by insulated cables. They generally met with ill success on account of defective cables. This was notably the case in the James River, "where a United States frigate hovered" for four hours over a mine consisting of a boiler shell filled with "several thousand" pounds of gunpowder and which refused during this entire period to respond to the frantic efforts of those on shore to make it explode.

There is at our United States Torpedo Station at Willet's Point in New York harbor a museum of submarine torpedo development. It is with the blood tingling with resentment, the cheek mantling with the blush of shame at our own impotence, that we turn to the evidence of our own weakness in 1873; our inability to resent a National insult by a decrepit European power; our perfect panic over the possibility of an attack upon New York City itself, following on the heels of the *Virginius* affair; and our own puny efforts to supplement our miserable land defenses with a defensive system of submarine mines that never would have worked because of lack of reliable insulated cable to operate them with. The incident was happily repaired by the explosion of twenty-one blasts of powder by a Spanish gun-boat in salute to the United States flag. But Congress was awakened finally, and a move made toward the rehabilitation of our navy, resumption of work in coast defense and the purchase in England of sufficient submarine cable to adequately supply all our important harbors with an efficient system of submarine mines.

Up to 1878 we had wires and cables for telegraphic service only and the overhead wires multiplied almost imperceptibly. In 1878 we were blessed with the advent of the telephone, which made gigantic strides in our cities, telephone wires within a few years many times outnumbering the telegraph wires. At about the same time we got our first electric light, but the development of this industry was much slower than that of the telephone.

About 1882 the electric railway was introduced, and by the end of 1886 we had roads on three different systems in eight cities. In 1887 the Sprague system was made a success in Richmond, Va., and the following year we find all these various systems absorbed by three giant rival electrical corporations, and the attention of the various inventors directed toward perfection of detail, standardizing of manufacture and the study of economy of manufacture and of operation. With the latter came the introduction, in addition to the trolley wire, of the heavy feeder systems now prevalent in electric railway operation.

Prior to this the extension of high tension arc lighting and the

alternating system of incandescent lighting had brought about very unhappy relationship between the electric lighting and the telephone interests. The telephone people had evidently raised the cry for putting the lighting systems under ground, for at the first convention of the National Electric Light Association, at Chicago, February 25, 1885, the entire discussion was directed to the existing demand on the part of the telephone companies for the forcing of electric lighting wires underground, because of their interference with telephone wires and telephone service. A committee was appointed to report at the next meeting of the convention. This report was made by Mr. R. W. Pope, who recites that the only experience thus far available in the United States, was that of the Western Union Co., who ten years before had put down English gutta-percha cables drawn in cast-iron pipes along Broadway in New York City. The insulation was destroyed by adjacent steam pipes, and the entire system abandoned as a costly failure. The convention then resolved unanimously that it was advisable to relieve the streets of the great burden of the telegraph, telephone and fire alarm wires, but that the heavier, stronger, better constructed lighting systems should remain overhead. The convention, however, did a wise thing in appointing a committee to follow the work of the New York Commission of Electric Subways appointed under authority of legislative enactment of 1885; for it was due to the vigilance largely of this committee, that the work of a non-expert Commission proved, from a technical point, so substantial.

At the convention of February, 1886, this committee reported that they had attended all the public meetings of the Commissioners of Subways, and had examined minutely over one hundred plans presented the Commission. Meanwhile the Commission, after considering all the plans presented, and the criticisms of this committee, decided that it was unnecessary to follow any patented scheme, and outlined the true requirements of a subway system — viz., a duct, permanent in its character, accessible at intervals by means of manholes, for the drawing in of cables and the tapping on of service connections, the cable to be made complete within itself with all necessary insulation.

Disappointed patentees thereupon had the subway law and the action of the Commissioners thereunder declared unconstitutional and improper. This caused a delay of a year, when the present Board of Electrical Control was constituted.

Meanwhile electrical engineers were working energetically at the problem. The American Institute of Electrical Engineers took advantage of the Electrical Exhibition of 1884 to meet in Philadelphia, when the attendance from abroad was unusually large.

Mr. Berthon, of Paris, described the underground telephone system of that city. Mr. Calendar presented at length a paper on "bitite or

vulcanized bitumen" cables, which he stated had shown two years successful service in England. Mr. Preece, Chief of the English Postal Telegraph Service, confirmed Mr. Calendar's statements, and said that in his country they did not discuss the *possibility* of underground telegraph or telephone service; that with them it was simply a matter of first cost. If they had more than fifteen wires to run in a trunk line, it was cheaper for them to go underground.

But these electrical engineers had more to contend with than the single engineering problem of putting their wires underground. In the National Electric Light Association they came in contact with the commercial feature of the problem, and again and again they uttered their semi-annual protest against the enactment of subway laws applicable to arc lighting wires, in one instance stating that the cost was prohibitive; that while the overhead arc wires cost 1½ cents per foot, the underground would cost 6 cents per foot. The fact is that in these days arc-lighting companies are compelled to pay almost twice the latter price for a first-class cable.

In 1888 (May), Prof. Plympton described the Brooklyn system of subways, enumerated the failure of cables therein, and stated that in no instance had arc-lighting wires been successfully buried.

Meanwhile the new Subway Commission had, under the advice of their attorney, forced all issues in New York City by actually constructing subways. Their engineer, before the National Telephone Association's Convention, September, 1888, reported about 2,500,000 feet of single duct construction complete in 37 miles of trench—19½ miles for telephone and telegraph, and 17½ for electric light. Mayor Hewitt, in August, 1888, had opened the Electric Light Convention in New York with a very happy address of welcome, but ending in a strong appeal to the convention to take up and solve the problem of putting their wires underground. But the cost to the already overburdened companies seemed beyond the possibility of financing, and the question was shoved off until the next convention, with the usual resolution in favor of putting the telephone and telegraph wires underground, and leaving the electric light wires in sole possession of the air.

The situation in New York City was now intolerable. Rival companies entered the same field. No regulations had ever been promulgated for the control of overhead construction. Pole lines existed upon either side of many streets; and as many as three pole lines were consecutively erected along the same side of one street—each line taller than its predecessor. Private telegraph lines had given way to telephones, and the disused telegraph lines had been abandoned to their fate. Entire trunk lines were abandoned in favor of new lines along better routes. Rival companies sought each other's customers

and added their service connections, leaving the old ones in place. And with all, the lighting companies had been compelled by the insurance companies to make use of a grade of wire whose only recommendation was that it was not so inflammable as the ordinary insulation of to-day. The insulation consisted simply of a tape impregnated with white lead. The insulation was no protection from shock, and much worse than bare wire, from the false sense of security that its presence on the wire might give to the uninstructed lineman.

Fire, shock, injury, death, were of so persistent recurrence that the authorities grew desperate. Finally, on October 12, 1889, a Western Union lineman was burned to death almost in front of the Mayor's office. Immediately Mayor Grant issued orders that all electric light lines not properly constructed and insulated should be destroyed. The work had barely commenced when enjoined by Judge Andrews on the representations of the companies that the Western Union's man had been shocked by his own wires; that the electric light wires were well constructed in accordance with the underwriters' requirements; and that the authorities of the city of New York had never prescribed any standard of line construction, nor indicated any specific defects to be corrected in existing lines. Matters thus remained in *statu quo* until another terrible death of a lineman, almost in reach of a crowded platform of the Ninth Avenue Elevated Railway station, at 155th Street, again wrought up the public's fears to the point of frenzy; and the Appellate Court, on December 13, 1889, vacated Judge Andrews' order, on the ground that dangerous wires were a public nuisance, and that the Mayor, or Commissioner of Public Works, the Board of Health, or any citizen would be warranted in the abatement of such a nuisance, even to the extent of the destruction of the lines themselves. Thereupon began a slaughter of the poles. Before January 1st, 4,772 poles, carrying 5,615 miles of wire, were removed from the streets. New York was in darkness, and not before the middle of February, when the first underground circuits were put into service, did a single arc armature turn over in public lighting service. The writer was called to New York to immediately look after the interests of two of the offending electric lighting companies, and to advise and assist two others belonging to a friendly faction. An immediate examination and test of cables available was made with the assistance of the officers of the U. S. Torpedo School, resulting in the contract for the entire output from two of the cable manufactories for a period of several months. The prices paid were exorbitant, but I am happy to say that every cable is in service to-day and apparently as good as the day put down.

From this time, therefore, dates the beginning of commercially successful underground electric lighting. During the past five years senti-

ment of antagonism has been gradually lessening on the part of the operating companies; and to-day we find many of them, of their own volition, placing their heavier wires underground. This is notably the case in Boston, where the narrow, crooked streets prevent the proper guying of pole lines to carry the heavy feeders required for railway service, and this part of the system is largely underground; and in recent construction in Chicago, where it was a physical impossibility to carry on pole lines the 75 heavy feeder sections used in the operation of the West Chicago Street Railway Company's lines. In both instances, however, these underground cables are going in in districts where under terms of franchise, overhead wires are permitted.

I have already stated the requisite of a subway to be purely the mechanical protection of the conducting cables. These two—the subway and the cable, may be combined in one, as in the Edison system; or subway and cable may be separate, as in the drawing-in system of New York. The Edison System consists of copper rods which are wound with jute, bound together and inserted in a wrought-iron pipe. A melted compound of wax, bitumen and linseed oil is then forced into the pipe, completely filling in all intervals between pipe and jute and copper conductors. These pipes, or "tubes" as they are called, are laid in an open trench end on, the conductors, three in number, projecting about three inches beyond the end of the pipe. The several rods are then connected end to end by connecting lugs, and a cast-iron box then placed over the joint thus made, and filled with a hot melted compound that never completely solidifies. If a connection to a customer is required, special three-way connecting lugs are used and a cast-iron three-way or tee-box permits the connection of a tube at right angles to the street line, directly into the customer's cellar, as in gas service. The straight-away boxes and the tee-boxes are interchangeable, so that the latter may be at any time substituted for the former, and service connections made at every joint at intervals of 20 feet 6 inches, if found advisable. The trenches are then filled in, a plank being commonly laid over the top of the tubing, in order to protect from the blows of a pick in subsequent street excavation.

The difficulty with this system is the necessity of reopening the street to lay additional or larger tubes as the system grows. This has been met somewhat by superposing in part the drawing-in system with spare ducts for additional feeders, the main or distributing tubes being put in of sufficient size to meet reasonable increase in business. Let me say that from its inception the Edison system has been for cities a complete system from dynamo to lamp, with every detail carefully worked out, and put in without makeshifts, *underground, and with the intention of its staying there.* These tubes have been purchased at prices simply

beyond conception, at times when copper rods and pipe were high, and the skilled labor necessary to handle such work much overpaid; when the system was protected by strongest patents, and users expected to pay right royally for the privilege of using. But we, who are using other systems, are confronted with the fact that, without exception, these Edison stations are making money to-day. This we cannot say in many other instances.

The second or drawing-in system consists of one or more ducts with necessary arrangements to permit of drawing in insulated cables and connecting them at intervals to house services.

It matters not whether the conduit be of any one of the systems in common use, provided the ducts be straight, smooth, sufficiently large, and with manholes at frequent intervals, so that the strain in drawing cables through be not so great as to injure them.

The various drawing-in systems are briefly as follows:

I. The Dorsett.—This has been used to a limited extent in New York, in Chicago, Minneapolis and elsewhere and is the original system put in in the city of St. Louis by the St. Louis Underground Service Co. It consists of asphaltum blocks 4 feet long by 1 foot square with 2½-inch ducts molded throughout their length. It is a relic of the days when it was supposed that the conduit itself should be an insulator—a feature that we now little care about. The ducts, if well laid, present a smooth surface in every way desirable for the drawing in of cables, but the size of duct is unfortunately too small to take in the present large sizes of telephone or telegraph cables, or the largest railway or lighting feeders of the present day.

II. The Johnstone.—This is a very completely worked out system, having in its lower section what are known as trunk ducts, running uninterruptedly from manhole to manhole, and in its upper section what are called distributing ducts, the cables therein being accessible at intervals for the purpose of making house connections. The system is entirely one of iron castings in 5-foot sections, the lower sections carrying the trunk ducts, the upper section or cover being removable, exposing the cables therein, and being made interchangeable with another cover having provision for handhole and lateral outlets for house services. The system was early adopted in New York, but abandoned because of the inherent expense and a disagreement with the patentee as to the royalties to be paid for its use.

III. A largely used system is that recently installed on Olive Street, in the extension of the St. Louis Underground Service Company's system to the Postal Telegraph Company's operating room in the Laclede Building. It consists of sheet-iron riveted pipe lined with cement, the interior of duct being 3 inches. These ducts are made singly in

8-foot lengths with male and female spherical joints at the ends. This construction insures good joints, comparatively few in number, and with excellent interior surface for drawing in cable. The ducts are laid singly in a row upon a base of concrete and in cement mortar. This, and all following systems, have the great advantage of adaptability to service requirement, in that any number of ducts from one up to the maximum can be laid along a certain route, and further, that there is a certain flexibility at the joints, permitting spreading of ducts, or slight variations in alignment to avoid obstructions in the trench.

Instead of the sheet-iron cement-lined duct thus described, we find in use wooden ducts of creosoted pump logs or slight modifications thereof, or ducts made of glazed tiling; of wire gauze supporting a molding of cement; of molded cement tubes; or, as in the later construction in the city of New York, of wrought-iron pipe. All these classes of ducts are generally laid as described above, in cement mortar on a concrete foundation, with a wall of concrete on either side, and a protective covering of plank or concrete.

At street intersections these ducts, as also those on streets at right angles, are brought into a common manhole. The cables are fed from drums on the street down through the manhole cover and into the ducts and then jointed in the manhole to the lateral or extension sections as the service may require. As these ducts end on the face of wall of the manhole, they are about 4½ inches apart center to center. The cables coming through them are bent around and carried along the walls of the manhole on racks, until they enter the ducts on the opposite side. This is necessary in order to leave a clear space in the center of the manhole for men to work. It is easy to see that with a large number of cables even the most careful arrangement on racks involves a very close bunching of these cables in their progress from the duct mouth to the racks, while the short bending of the cable at the duct mouth at least does not increase the power of the cable to resist rupture and burn-outs. It is at this point almost without exception that break-downs occur, and at this point the break-down becomes most serious as the burning cable injures the one in contact with it; this gives way, then another, until every cable in the manhole may be put out of service. It is for this reason that the cable munufacturer prefers smaller subways, fewer ducts and separate subway for the wires of different classes.

As to the cost of subways, this will depend upon the character of pavement, of subsoil, the number of obstructions to be removed and replaced or avoided, and the frequency of manholes. It is evident with 3-inch concrete protective wall a subway of one or two ducts is comparatively expensive. For twelve ducts or over the cost per foot of subway is almost proportional to the number of ducts and can be assumed approx-

imately as from $1,200 to $1,800 per duct per mile. Messrs. Maver & Lauterbach, of the New York Subway Company, are responsible for the statement (February, 1890, meeting of the National Electric Light Association) that the subways in that city cost as a minimum $3,000 per mile. The Subway Company charges an annual rental of $1,000 per mile of 3-inch duct. This has proven a heavy burden upon the electric lighting companies; the prices for service are necessarily excessive and the extension of business very slow.

One word as to the room necessary in the streets for subway construction. There has been much unnecessary misapprehension regarding this point. A single 3-inch duct will take a 100-pair telephone or telegraph cable. The equivalent pole line would be one carrying twenty 10-pin cross arms. For electric lighting and power the same concentration is not possible, although I have here a single cable capable of carrying 1,500 horse-power, the equivalent of nearly four of the largest sized cables ever strung overhead—such as you will note along the east side of Fourth Street on the new Arsenal Street Railway pole line. Four of these cables in the air require a space of 4 square feet; this cable in the ground with its duct requires a space of 20 square inches—about $\frac{1}{30}$ of the air space. Much misunderstanding too seems to have existed regarding the possibility of one company blocking off future competition by its subway construction. This is an error. Ordinarily subways are constructed in the unoccupied area vertically between the water mains, which in this climate are laid about 5 feet below the street surface, and the gas mains, which are generally laid as shallow as possible. In this space of 36 inches, with a roadway of 30 feet width, could be placed 750 ducts carrying 150,000 telephone and telegraph wires, or cables carrying 1,125,000 horse-power; and without undue expense, by constructing manholes of proper depth, such a subway could be carried under or over, or communicate with a similar subway along an intersecting street, the manhole depth being adjusted so as to go through the space between the water pipes and the sewers, or, if necessary, under the sewers. This is an extreme case, but it serves as an illustration. But, as a matter of fact, in a space of 5 feet between curb line and center of street there *could* be constructed four separate and distinct subways giving to each of four companies fourteen ducts, capable of carrying for each company 2,800 telephone or telegraph wires, or cables carrying 21,000 horse-power. The same thing *could* be repeated on the other side of the street, and the railway companies carry as much through the center of the street. All this without covering up water and gas pipes or going, except at street intersections, below the depth of 5 feet under the street surface.

As for the legislation to accomplish the undergrounding of wires, I hesitate before men who have given this subject so much practical thought

to speak. The general view taken by the courts in this matter is that cities have a right to regulate the installation of electric wires and can compel the same to be placed underground. Where existing companies are in the possession of overhead rights and making use of same, these can only be taken away collectively; telephone, telegraph, police and fire alarm telegraph, electric light, power and electric railway must all go underground together. But the manner of procedure must be such as to give to the servitor the equivalent right underground of its existing charter rights overhead. And the method of procedure must not work undue hardship (such as the allowance of too short time for the change) or amount to a confiscation of property (such as the taking away of rights of ownership and the substitution of leasehold rights, especially for a period less than that of the franchise); or the compulsory placing of the trolley wire underground where the expense amounts to confiscation and the practical results are doubtful. But every other existing wire can be placed underground in the business districts, without exorbitant cost and to the great advantage of the public and the operating companies.

If we approach the subject in a spirit of justice and of fairness to our electrical servitors, I believe that there will be no trouble in securing the undergrounding of all wires (except trolley wires) within the limits of our business district before the year 1900. This Club, representing the leading corporate interests of this city, representing the leading taxpaying interests of this city, is in position to use its good offices in bringing about a full understanding on any points of difference between the electrical corporations and the city's legislators. This done, right merrily will we see the poles fall on Broadway, and Fourth Street, and Olive Street, and Pine and Chestnut Streets, and the city take on an improvement in appearance that will astound the oldest inhabitant.

I have here for inspection of those who desire to look them over the underground franchises of the largest companies in the country, the Edison Companies of Boston, Philadelphia, St. Paul and Milwaukee. I have also a typical electric railway ordinance in that of the North and West Chicago Street Railway Companies; also the franchise of the Northwestern Telephone and Telegraph Company operating the exchange of St. Paul and Minneapolis.

I have also a number of samples of cable which I will pass around for examination. They are all labeled so as to indicate their use and service capacity.

Editors reprinting articles from this journal are requested to credit both the JOURNAL and the Society before which such articles were read.

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RECENT IMPROVEMENTS IN MAINTENANCE OF WAY.

BY BENJAMIN REECE.

[Read before the Technical Society of the Pacific Coast, April 3, 1896.*]

WITH the constant increase of railway mileage in this country, the struggle for existence has been very bitter, and doubtless will become more so.

The construction of railways has been encouraged by the general public for the purpose of stimulating competition, and doubtless many lines have been poorly located, and still more poorly built, for the mere profits of construction. These have been developed generally by promoters and speculators, who have availed themselves of the easy money markets which prevail at times when railway securities are in special demand, as in those periods of great activity and rise in stocks, which are generally known as business booms.

Lines thus built frequently enter into a competition in which rates are indiscriminately cut, and demoralization to railroads and commerce alike is threatened. Capricious and illogically cut rates are the despoilers of honestly managed properties and the debauchers of the public confidence. The lines which precipitate these struggles are generally those which are the least prepared for any permanent reductions.

The public, thus looking for competition and failing to recognize the difference between permanently low and cut rates, is impatient at

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any thought of pools or combinations, which in themselves would check many of the evils which the Interstate Commerce Bill is intended to correct. The gradual lowering of established rates has been, and in a measure it will continue to be, the necessary consequence of our economic conditions, and in the ultimate struggle the lines of low capitalization, consistent with a minimum of cost for repairs, will ultimately set the pace.

Evidently this implies a management in which the wasteful expenditure, or still more costly neglect, in maintenance of way must be corrected.

Even now we are confronted with a constant lowering of rates which, in many instances, has become necessary in order that we may market our products at all. Fifteen years ago our Western farm products had almost full possession of the markets of western Europe, but the extension of railways in Russia, Hindoostan and South America has resulted in the opening up of so much new territory that the prices of wheat have been reduced one-half, and in the rapid colonization and development of Africa appears the specter of a still more dangerous rival.

With this constant lowering of the prices of Western products freight rates must logically fall, for our railways carrying seaboard shipments, which really control the prices of our superabundant products, are no longer restricted to national competition, but find themselves in active rivalry with the developing railway systems of the Continents.

The panic of 1873 was precipitated by excessive railway construction, but that only involved a waiting for this rapidly developing country to restore the equilibrium. This was much aided by the general adoption of the Bessemer steel rails, which have saved to the railroads those enormous expenditures which, even under the light traffic of that time, the rapid destruction of iron rails had involved.

In 1879 the revival came, and with it came an increase in loads for cars, the first suggestion being to load the cars of 12 tons capacity, which then prevailed, up to 13½ and as high as 15 tons. This was resorted to as a quick and ready means of increasing the carrying capacity of the lines which at that time was utterly inadequate to convey the tonnage to be hauled. From that time dates the construction of cars of increased capacity, until 40 and even 50 tons per car load has now been reached.

In connection with increased car loads is also noted the demand for increased train loads involving heavier motive power, which has proceeded with undiminished energy. Indeed, in general terms, it may be stated that the period from 1880 until the nineties was one in which economies in the cost of transportation proper was the ruling thought.

But time as well as cost of service is frequently the basis of competi-

tion, and it has occurred that while wheel loads have been increased the speed of trains has also been accelerated. On but few railway lines did the improvements on the track keep pace with the severity of the service required of them, and not infrequently the road departments on railways were engaged in a hard fight to keep their tracks safe for the running of trains. It was at this juncture, from the very exigencies of existing conditions, that we can date the recent improvements in the maintenance of way on many lines. To this general statement there are, of course, as you are aware, many notable exceptions.

The panic of 1893 proved an inexorable educator in pointing out the fact that the earnings of the prosperous must in part at least be expended in capitalizing the expenses of maintenance during the years of depression.

With decreasing tonnage and diminishing rates it was learned that money had to be saved even if money had to be expended for the purpose, and to those lines which, in large measure, have fairly maintained their tracks in the past must we look for existing as well as prospective improvements in maintenance of wa

The improvements may be classed into those of refinement of track and of those permanent improvements looking to a diminution in the cost of repairs; but as, in a great measure, these betterments are largely obtained by the same methods I will attempt no division of them. The one, of course, has been rendered necessary by the marked tendency to increase speeds in passenger service, the other has been rendered necessary as an essential to survival, as on many lines the annual cost of repairs were so burdensome as to periodically call for the appointment of receivers, which, in some instances, entailed the loss of the property, while in others it was employed as an instrument by which the physical condition of the road could be restored to where it should have been preserved.

On roads, both of high and low degree, there is considerable activity in providing a good ballast bed for the support of the tie, and to give stability to the track as well as to reduce the annual charge for labor, which had been required to keep in poor surface and line, track which had been formerly surfaced with the soil.

Gravel, cinders, furnace slag, broken stone and burnt clay ballast is being hauled, in some cases, two or three hundred miles, for the purpose of this important betterment, and wherever it has been done, the wisdom of the move is vindicated in the great reduction in labor, cost of maintenance, to say nothing of the saving to rolling stock, motive power, rails and fastenings, all of which were subject to the shocks and impacts due to defective surface and imperfect line.

Roads differ somewhat as regards sections of road-bed between

themselves, yet there is observed that greater attention is paid to their individual standards, and greater uniformity exists in this regard than ever did before.

A radical increase in the weight of rail section is also noted, the principal Eastern lines ranging from eighty to a hundred pounds per yard, while upon the coast I learn your increase is from sixty-two to seventy-five. These heavier rails, affording much greater stiffness as beams, results in less wave flexure, hence affords a more stable track, less undulation of rail, pulling of spikes, and not infrequently pushing of ties in the ballast, and the greater benefit derived from the heavier rail is to be found rather in the saving of labor than in the additional wear of the rail itself. In our American practice, we still adhere to the hook head spike, practically the same as was used with the earliest T-rails. While this subjects our tracks to more excessive creeping of the rail, which, however, is measurably reduced with the deeper, heavier sections, yet it does not pump the ties in the ballast, as is found to be the case with the tracks laid with T-rail screwed down to the tie on tie-plates, as in the Continent of Europe. In my opinion, the nearer the surface you can confine any vertical movement of your superstructure the more permanent it will be, and the less costly to maintain, and there has been but little tendency to depart from its use, although many improvements have been attempted with a greater or less measure of success.

As a fastening, the angle bar appears to be growing in disfavor. Much was expected of the long angle bar supported by three ties which was first applied on the West Shore Railroad during its construction in 1881 and 1882. That it has not given the satisfaction expected of it is evidenced by the fact that many of the lines who have used it have returned to the shorter bars. On the lines ranging through Indiana and Ohio, I have heard it claimed by engineers that, when tightly bolted, the long bars offer sufficient resistance to the expansion and contraction of the rail as to kink in the one case, with the tendency to break in the other. Of course, when the bolts are loosened, the joint is necessarily imperfect. Mr. Torrey, Chief Engineer of the Michigan Central, has been experimenting with rails, 500 feet and 800 feet in length, respectively, using expansion joints for same. These rails were very closely watched, observations being taken as to expansion and contraction three times daily. Mr. Torrey is so well pleased with the result as to make a further experiment covering a mile of track. As you all know, some lines have used and are using rails of 45 and 60 feet in length, with a view of eliminating the joints. Several new joints, generally patented devices, have been placed upon the market, many of them having secured recognition on important lines, and are said to be giving good results, covering from two to four, or even five years of service. The trouble with the

angle bar rests in its limited bearing surface under the head of the rail. This, in a few years, results in the wear of the angle bar and a corresponding wear of the under head of the rail at the ends of same. In 1879 I put in a cold cutting rail-saw to cut off the dipped ends of 30-foot rail, reducing them to 28-foot lengths. With these, I laid branch-track, attempting to use the old angle bars, but found a movement of the rail from the start. Upon examining the bars, I noticed them sufficiently worn, as to leave a well-defined piece of metal in the center, in the shape of an inverted V where the angle bar had been more or less protected by the expansion opening left between the rail.

It is because of this feature that nearly every joint of recent design involves the bridge affording the rail an undersupport resting upon and bridging the space between two ties. That a radical change in the fastening of rail joints will shortly come about I have but little doubt.

While the main expense of maintenance is that of labor, it is to be regretted that as a general thing the personnel of the section gangs throughout the country is deteriorating in the East, particularly the Italian is gradually displacing the older section hands. In the South possibly the negro laborer may be improving, certainly he ought to be if he benefits by experience. In the Middle States also the native German and Irish section hands are gradually giving place to laborers of a lower grade; this of itself demands more constant and better supervision and the introduction of all available checks upon them to secure that thoroughness of work which alone can make refined and enduring track. It is a good sign, however, that recently, while on an inspection trip on Illinois Central, I saw a roadmaster censured by the chief engineer because the new rail, just laid, showed a sixteenth of an inch open gauge.

After many years experience I am fully convinced that track can be laid to a perfect gauge in renewals at very little greater cost than when careless and hastily done. Such track, thoroughly tamped and well lined, is not only enduring, but the most economical in the end. The refinements of a main line are not required upon the branches, but even on these thoroughness of work up to the standard of excellence required, insures permanence and less cost than the constant botch work which not infrequently prevails on lines where the handcar, moving from point to point, is in more frequent use than other tools. The proper policing of the track is undoubtedly of great moral benefit to the man, but well defined lines, uniform section of ballast, and track properly cleaned of grass, is conducive to an *esprit de corps*, which is made manifest in more energetic and ultimately in more intelligent labor. In comparing the cost of maintenance on different lines in the various State reports and other sources, it has been my experience that, as a rule, on lines of similar traffic, those showing the cleanest rights of way, and best defined road-beds, have shown the lowest cost per mile.

Twenty years ago the cost of rail renewals, next to labor, was the largest item of expense. At this time, although the Bessemer steel rails were much more expensive than iron, yet they were being very generally introduced upon our railways, the enormous annual cost of the renewal of iron rails having almost threatened the life of our railway system. With the cheapening of coal, the development and opening up of Bessemer ores on Lake Superior, the cost of Bessemer steel rails has been so reduced that their present market price is not more than 40 per cent. of the cost of iron in 1872. Not so with ties, however. The gradual reduction of our forests, particularly in the older section of the country, has tended to a constant increase in their price, and where, under the moderate traffic of that early period, they gave service until removed by the cause of decay, they are now frequently destroyed prematurely by the action of the rail under the heavy wheel loads, higher speeds and increased traffic of to day. So that while the cost of rail renewals were four or five times those of tie renewals in 1872, the figures were almost reversed and ties, next to labor, have become the most considerable expense in the maintenance of way, and the cost of tie renewals are now from two to four times the cost of rail renewals, according to the location of the line upon which the comparisons are made. For many years this question of ties had received but little attention. What had been true in an early day was supposed, or at least assumed, to be measurably true to-day. As the question was agitated and studied the question arose as to how the cheap softer woods could be made available for use under heavy traffic. Some of these woods are very enduring against decay. Such are the cedars of the Lake region, the cypress of the Gulf of Mexico, and the redwoods of California, but their usefulness was much impaired by reason of their cutting in and being destroyed by the action of the rails. Other soft woods which could be secured at low cost were susceptible of chemical action which would add greatly to their lives, but like the more enduring groups they were rapidly destroyed by the action of the rail. In the treating and mechanical protection of ties the Southern Pacific line has been one of the most fearless and at the same time successful pioneers.

Perhaps, in the whole range of maintenance of way, the most striking feature is the revival of tie or wear plates which are now being very generally used throughout this country and Mexico. Plates were early used, but were of such designs that they only partly saved the tie and introduced difficulties almost as objectionable as those which they were intended to correct. The first designs were based upon the mistaken assumption that the tie was destroyed by the direct crushing down of the fiber by the indentation of the rail, whereas the breaking down of the first wood cell is followed by rasping and throwing out of the fiber of

wood, due to the slight back and forward movement of the rail. Any one who has observed a cut tie must have seen that the cut sides are walled up almost as if cut with a saw. There is no drawing down of the fibers as would have been the case had it been the result of indentation. This error led to the idea that a greater distributive area was required, and induced the development of long wide plates to support the rails, whereas in fact it was only needed to confine and protect the wood fiber from being displaced by the rail, and thus confined, after being compressed so far, sawdust itself would have supported it. You will at once see that a long thin plate would necessarily curl at the ends and a constant thickening to avoid this evil was the result. The plates being loose would jump from the tie, give out a disagreeable metallic ring, and would indent the tie sufficiently to leave a receptacle for water, which the undulating rail acting upon the plate would literally pump into the tie, and hence cause premature decay of the tie under the rails. Nor was this all. The heavy plates working loose from the tie acted as anvils under the rail as they received the shock of every moving wheel. This led to a spotting of the rail by reason of lamination, and some 40 miles of such plates having a shoulder abutting against the outer flange of the rail were removed from the Pennsylvania over twenty years ago. The early experience with such plates was such that they were universally condemned, and it is only through the long success of applications hesitatingly made that the revival has become complete.

Before rail movements had been closely watched it was assumed that a well spiked and well bedded rail could be turned over by the moving train. It was also assumed that the engine exerted a direct lateral thrust, sufficient to overcome that exerted in the direction of gravity from which it derives its tractive force, the fallacy of this is at once apparent. This suggested the use of rail braces, which are now recognized as failures. It also suggested the outer shoulder on the plates, which, though of some little advantage in saving the spike from the wear due to the slight undulations of the rail, necessitates modifications of designs at once injurious to both tie and plate. The theory is that the shoulder will protect the spike from abrasion, but manifestly if the plate has a plain under surface, the rail pressing against the shoulder will cause the plate to impinge upon the spike and wear it away, where it cannot be seen, which is even worse than where the same conditions exist in the light of day, visible to track walkers and section men. This led to spurs, prongs and flanges which cut the tie transversely of the grain, in order to hold the plate securely against such movements, but with the constant vibrations of passing trains the transverse openings thus made in the wood are widened, and as the tie softens they loose their hold at the very time when the plate is supposed to be

of greatest value. The development of the last eight years has shown that where the hook head spike is used to fasten the rail to the ties, that any successful tie-plates must automatically unite themselves to the tie, becoming practically an integral part thereof. This has been fully accomplished by the use of plates having longitudinal flanges, which separate without splitting the grain of the wood, and so fix themselves firmly to the tie-plate in the general form of a channel iron, have been found very effective.

I need not call attention to the fact that the channel iron form is particularly well adapted to confining and protecting the wood fiber from displacement by the rail. I have seen a plate of this type $3\frac{3}{4}$ inches wide by 8 inches long protect a chestnut tie in the tracks of the New York, New Haven & Hartford Railway for six years, when adjacent ties unprotected had been cut down by the rail, having 5 inches width of base for more than an inch in depth. In the indentation of timber its structure is such that it is pushed out transversely and does not elongate, hence with timber at all fibrous such plates become tighter and tighter with use, and in the case of oak when being removed, I have seen them lift out bodily from a tie the wood lying between the flanges of the plate. Many minor changes might be enumerated, but time will not permit. I am, however, glad to say that more and more attention is being attracted to maintenance of way, and there is a growing disposition to select technically trained men for the supervision of the work, which gives promise of a wider field of labor for the civil engineer.

DISCUSSION.

Mr. J. H. Wallace.—Using, as we do on this coast, a soft redwood tie which is rapidly cut out under the rail, but which, when not destroyed in this way, will resist decay for many years (we have ties in sidings, that are perfectly sound after forty years of service), we early began experiments looking to the adoption of some method to prevent this cutting, and thus lengthen the life of the tie.

At first, we labored under the same mistake as others referred to by Mr. Reece, and supposed the wear was due to the crushing of the fibers of the wood by the load put upon them. With a view to overcoming this, it was at first suggested that larger ties be used, spaced closer together, thus endeavoring to diminish the pressure per square inch on the wood.

Efforts in this direction had not progressed far when it became evident that the wear under the rail was due not to the destruction of the fibers by compression, but to their being gradually ground or worn away by a slight longitudinal motion of the rail, aided by the sand and grit which found its way between the rail and tie.

The remedy for this is, undoubtedly, the use of tie-plates. As yet, our experience with them is limited ; but, so far as we have gone, we are very well satisfied they are going to make the redwood ties last about three times as long as formerly.

Mr. W. G. Curtis.—I might say, in corroboration of Mr. Wallace's remarks, that probably not one per cent. of the redwood ties removed from the tracks are removed on account of decay. The failure is almost invariably due to the cutting out of the tie under the rail.

About ten years ago we put some experimental plates upon the redwood ties on the shore end of the Oakland mole, watched their wear and kept a record of them. I thought I had the figures here, but find I have not. The ties were cut down about one and a quarter inches under the rail by the passage over them of about thirteen million tons of trains. The life of the redwood tie is not measured by time, but by the traffic.

We have ties in sidetracks to-day, a few, that were laid, I think, in 1856, forty years ago, and they are still perfectly sound and are good ties. Of course, but little traffic has passed over them.

We experimented on the Southern Pacific lines ten or twelve years ago with plates, and our course has been very much like that described by Mr. Reece. We had the idea at first that a greater bearing area was needed, and made very large plates. We were disappointed to find that they did very little good, and finally came to the same conclusion Mr. Reece has presented, that it is the rasping motion, the sliding motion of the rail upon the tie, almost imperceptible though it be, that cuts out the wood. We tried fastenings that would secure the rail, plate and tie more closely. In one experiment we used a " U " bolt passing through the tie, with the nuts at the upper ends, and washers so shaped as to engage the rail flange, in this way fastening the rail and tie together ; but that did not seem to meet the requirements either. As a result of our experiments, our conclusion is that a plate, to be effective, must either be very heavy or be attached to the tie; and as a plate that can be attached reasonably well to the tie can be made very light, and at a much lower cost than a heavy plate, our ultimate conclusion has been in favor of the smaller plate attached to the tie.

METROLOGICAL STANDARDS AND GAUGING IMPLEMENTS.

By J. Richards, Member of the Technical Society of the Pacific Coast.

[Lecture delivered before the Engineering Classes at Leland Stanford Junior University, Palo Alto, Cal.*]

It is a curious and even anomalous fact that throughout the whole realm of nature there is no uniformity except in the element of time. The inevitable laws that govern forces and motion, the endless cycle of causes and results that form the basis of physical science, point to uniformity in matter as a sequence or condition of these invariable phenomena, but this is not the case. There is no uniformity in matter.

No two persons are alike. No animal, tree, shrub, plant, leaf or even a blade of grass has its precise counterpart in nature. Among a thousand faces that we know, each is distinct, and among the millions that we do not know this distinction goes on without any limit that we can conceive of. It is possible that no two grains of sand are precisely the same. There is no regularity of temperature or weather, no uniformity in matter organized, active or inert, so there is no fixed material basis from which a natural standard for metrology can be derived. Distilled water, we may say, is uniform in weight at some assumed level, the surface of the sea for example, but how are we to determine a specific quantity of distilled water or other liquid, without some means of measurement?

Lineal measure must be the base of all. By this are determined weight, capacity, surfaces, solids, and, indeed, all common measures. The metrical system is an illustration of this; the meter, an arbitrary lineal standard, is the base of the whole.

Some centuries ago this difficulty of standards became apparent, and there was a search extending over about two hundred years in attempting to derive from some natural source a lineal measure that could be appealed to in case of doubt, or the loss of standards derived therefrom.

This search for a natural standard for lineal measure in England and France forms a very interesting history that we need not follow out here, farther than to say that the two nations started out on different roads that after long and tedious experiment came together, because the search was abandoned by both countries.

The English scheme was to derive a lineal standard from time, or,

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as we may say, from the motions of the planets. Time is a constant and uniform element in the great economy of nature, divided with accuracy down from years to seconds, or, as we may say, with present knowledge, from centuries to seconds, and a measure if derivable from time could always be reproduced.

The method attempted in England was by the vibrations of a pendulum in a vacuum or at sea level in an undisturbed atmosphere. This was a very ingenious idea, and came near settling forever a standard for lineal measure. As a pendulum swings in equal time, irrespective of range, it is easy to adjust one to beat to seconds, and if this length could be translated to a measuring implement a similar standard measure could be derived in any part of the world at any time.

There arose, however, some serious impediments in these experiments, one of which you can easily imagine; that of determining the length of the pendulum after it had been adjusted to beat seconds. The method was to place fine pivot points at both ends of a symmetrical bar of metal, and then reverse it, to swing first on one end and then on the other, but there remained still the difficulty of transferring this measure, so the scheme was finally given up after a half century of experiment.

The French people attempted to derive a lineal standard from material nature, the ten millionth part of a quadrant of the earth's meridian. To determine this a degree of longitude was measured between Dunkirk and Barcellona, and the meter was derived from a subdivision of this distance, but there arose great contention over the method and results, and the French then, as the English had done long before, abandoned the scheme of a natural standard, and legalized the particular metrical standards then made, and took the required precautions, as in England, to deposit duplicates in different places, so that their loss could not occur. There was a great ceremony over this event during the reign of Napoleon II, and this arbitrary standard is, as you know, fast becoming that of the whole world, as it ought to do with all possible haste, being decimally divided.

When standards are arbitrary it is nonsense to talk of a national one. One standard is just as good as another in so far as authority is concerned. If any nation had succeeded in determining a natural standard, the case would be different, but an arbitrary one may be a yard, a meter or any other unit. There is nothing national about it, and cannot be.

The English, and to some extent the American idea of a meter is that it is a French measure, because France first adopted this unit, but being an arbitrary measure it is not French any more than it is English or American. It is only a matter of agreement, as the English yard is

with its division into inches and feet, with divisors of three and twelve instead of by ten, as we compute in common numbers.

I am sorry that the time at command does not permit more to be said of the curious facts and procedure that are embraced in this history of standards. It is extremely interesting, but not very useful in a practical sense, unless to dissipate some notions commonly entertained about such standards.

The true standard in this country is the meter, legalized in July, 1866, decimally divided downward to the millimeter, and with multiples upward the same, to the myriameter, but by custom, and following the British measures, our machine work is mainly with measures corresponding to divisions of a yard, with divisions downward of three and twelve, as before remarked, stopping at an inch, which is twenty times too large for convenience, and going up by factors of 5½, 40 and 8 to a mile, all of which is as absurd as it is inconvenient.

Other measures of weight, capacity, surfaces, solids, and so on, are as bad or worse, because we have two standards for weight and two for capacity, both in common use, divided in a manner that conforms to no conceivable system of order or relevancy, and explainable only on the grounds of accident, dating from a time and from circumstances that have nothing to do with modern methods—a tradition that would be out of place in the realms of imagination, to say nothing of the exact arts and sciences of our time.

The gauging implements now in use in this country, and by means of which the dimensions of machine parts are determined, are, as before said, derived from the British yard, expressed in inches and fractions of the same, mostly fractions, indeed all fractions, except for four implements out of a set of thirty to forty pieces, as any table of sizes will show.

These gauging implements consist of movable or adjustable calipering machines, fixed calipers, pins and collars, internal gauges, test rods, reamers, mandrels, and so on, adjusted to various degrees of accuracy; for example, to a five or twenty thousandth part of an inch in classes that are sold at different prices according to the accuracy guaranteed by the makers, as the published lists will show.

In 1860, when my connection with this matter began, there were no gauging implements in this country, except Whitworth pins and collars, imported at an expense of $300 to $600 a set, according to the number of sizes embraced, and these gauges were found only in a few of the largest shops. Such gauges are only for reference, from which other implements are made, hence did not meet the real want of gauges that could be given to the men for practical use. Some firms had made forged caliper gauges with round or curved contact points, but there was no manufacture of standard gauges in this country, nor was there in

England, except of pins and collars, down to 1878, as some future explanations will show.

With this much in respect to the derivation and nature of gauging implements, I will now revert to the history of their manufacture in this country, in so far as I had a part in this matter.

This is done with some diffidence, and the excuse for introducing a matter so personal in nature must be the great interest I once took in the subject, and a belief that among the few contributions I have been able to make to the advancement of constructive practice, this is by far the most important and the one I especially desire to be known, if any at all, when my work is ended.

In 1862, when foreman in the works of the Ohio Tool Co., at Columbus, Ohio, I had occasion to make some duplicate work, and not having any means of attaining standard sizes I sent to Jones & Laughlins, at Pittsburg, makers of cold rolled shafting, asking them to send a piece of 2-inch shafting that would fit the Whitworth collars they used in their rolling processes. A selected piece of this shaft, about one foot in length, two inches diameter, became a standard, from which was derived a series of sizes from one half to three inches, in the following manner:

The cross-feed screw of one of the engine lathes was measured with a rule, and found to be tolerably accurate, the pitch being eight threads per inch. A conical pin of cast iron corresponding to one end of what is called a conical testing standard shown in Fig. 1, was put in this

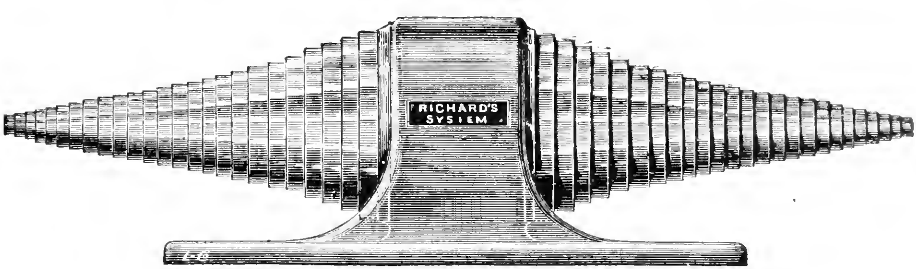

FIG. 1.

lathe and turned in steps by eighths and sixteenths of an inch, the same as in the drawing, but was left a little large. Then a finely tempered square tool was put in the lathe and its edge set true or parallel to the work. The cross-feed screw was provided with a disk divided into four parts, with a detent that would lock it at these four points. The 2-inch step on the cone was then turned, or scraped until it would caliper the same as the piece of shafting before mentioned. Then the tool was advanced a quarter or half turn and fed over the next step, and so on down to the half-inch size.

The same process was gone through from the two-inch step upward to the three-inch one. This cone was mounted in an inclined position on a cast-iron base and became a standard for sizes, resting it is true, on a very uncertain standard, but much better than no standard at all.

It was soon discovered that fixed calipers were required, and I proceeded to make these by cutting out lune-formed pieces from sheets of cast steel, also had some made from forgings of cast steel. A set of these gauges, about forty in number, was sent to Messrs. Brown & Sharpe, at Providence, R. I., to be ground to size, with flat points, and I believe were the first gauges made in this manner. Previously the points had been made curved or convex, offering only line contact to withstand wear. A set of these gauges were taken to Messrs. J. A. Fay & Co.'s works, at Cincinnati, Ohio, in 1865, and are no doubt in use there at this time.

Patents were taken out on the lune-formed, flat point calipers, and on the corrective cone, in 1867, but various circumstances prevented farther work on gauges until 1869, when I went to Philadelphia to found if possible the making of my gauges and corrective standards.

Everyone regarded the matter of such gauges as a mystery, and set small value on the audacity of a young man from Ohio, who proposed an innovation on the Whitworth system. I learned, as afterwards proved almost true, that the making of gauges was in some respects a mystery, and that no one knew how the processes were carried on, but the main impediment was that I proposed a new system.

I went into various shops to explain how pins and collars were of no use but as a reference, cost too much for common use, and were a foreign product, but no one would aid or join in such an undertaking, and I went on to England, where at the expense of a good deal of time and money, and from such information as could be gathered, the conclusion was that the means I had at command would be of no use in founding such a business, and the scheme was reluctantly abandoned until 1872. Then having more means I concluded to go on again, and rented one of the front offices in the Franklin Institute building, in Philadelphia, and arranged to have room in the basement to carry on the manufacture of gauges.

In this office were prepared the designs and detail drawings for ten special machines adapted to the various processes required in making calipers and corrective gauges. These machines, I mention with some pride. They are all in use to-day, and, in so far as I know, have not been much modified, although others of various kinds have been added.

A contract was made with Baxter D. Whitney, of Winchendon, Mass., to construct these machines, which he did with an accuracy that it would be hard to excel at this day. The work occupied about a year,

during which time I was in England, and then came the great panic of 1874, which stopped all productive industry in the way of implements of every kind. No one could conceive of what was to come; shops were closed, and skilled mechanics had to beg for their bread.

My gauge-making machines were coated with lead and tallow, boxed up carefully, stored away at Winchendon until August, 1877, when they were sent to Philadelphia, set up, and the gauge works, as we supposed, were founded, fifteen years after the first outfit of gauges was made at Columbus, Ohio, but the matter had been followed in one way or another all this time, in this country and in England.

In 1875 or 1876, Prof. John E. Sweet, at Cornell University, began and carried out there some very complete experiments in making standard calipers that deserve notice and commendation in any history of the art in this country. Some very accurate caliper gauges made at the University were exhibited at the Centennial Exhibition of 1876, with much other mechanism designed by Prof. Sweet that attracted wide attention. The first straight line steam engine, for one thing. The calipers were remarkably good examples, with broad flat points, hard and parallel, but Prof. Sweet, in talking of them, dropped a remark that became significant some years later, as will appear further on. He said: "We will not make any more of these calipers."

I will now quote briefly from a paper of mine read before the Franklin Institute, about 1878, when the various circumstances were better remembered than at this time:

"It was thought that in a month or so calipers and corrective gauges would be ready for sale, but these expectations were foiled by several circumstances, principal among which was the failure of the measuring machine, fitted with graduating screws made at the Whitworth Company's works in England, and guaranteed as to accuracy.

"This matter had before been thought of, but there was scarcely a doubt that the pitch of the screws was correct. Subsequent experiments, however, proved that not only the aggregate pitch was wrong, and the screws not parallel, but the relative pitch in so short a length as seven inches would not do to depend upon. The screws were, no doubt, as the Whitworth Company afterwards maintained, carefully made, but the delicacy of measuring tests demands more accuracy than can be attained by the pitch or movement of screws.

"The first experiment in measuring was made by preparing six rods of Stubb's wire, the points nicely finished, and the central part covered with several layers of thick soft paper to prevent induction. These rods were carefully fitted into the machine when set at six inches, temperature and other conditions being carefully observed. The rods were then uncovered and fitted into a groove cut on the side of a bar of pine

wood, and taken to Messrs. W. B. Bement & Sons' works, where a Whitworth master screw, with the necessary conveniences for testing the rods, was supplied, and even the experiments conducted by the firm, who were kind enough to take a great interest in the matter. By careful comparison it was found that the measuring machine in comparison with the screw recorded about one in ten thousand short. This, of course, stopped gauge making for the time. The test rods were then taken to London, and in three separate experiments on different standards—two by myself and one by Gen. B. C. Tilghman, member of the Institute—it was found that the rods were short, the variation being but little in the three cases, and corresponding very nearly with the less perfect experiment at Philadelphia.

"The next operation was to procure four standard test rods, from Troughton & Sims, of London, adjusted to the imperial yard of Great Britain and its divisions, by which the measuring machine in Philadelphia could be adjusted. Such rods were prepared in London with great care by those having access to the imperial standard, and my son, Mr. George Richards, then in England, brought them out to Philadelphia, and began the correction of the measuring machine, proving by combinations of the rods comparing with Whitworth gauges, and other references, but especially by combination. In the meantime another set of test rods were preparing in Manchester, England, and were forwarded to Philadelphia to prove the first set, and also the machine, which had then been tolerably well adjusted."

The adjustment of this standard machine occupied one month's time. The room was kept at one temperature, as nearly as possible, and thousands of readings were taken off, and when finally done, and the screws calibrated, the profile of error was curious to observe; the profile of one screw was convex, so to speak, and the other concave in respect to the axes.

Fig. 2 is a side elevation of this machine now in use at the works in Wilmington, Del.

I will remark here that any screw of reasonably accurate pitch can be made to measure or move for delicate measurements if its errors are translated to the reading scale, that is, if the scale or the index point on the scale, is arranged to vary with the errors of the screw. Suppose, for example, that the pitch of screw varied $\frac{1}{100}$ of an inch for each convolution, either long or short, this would make no difference if the scale from which readings were made was adjusted forward or back $\frac{1}{100}$ of an inch at the same time. This is the method of adjustment adopted for all measuring machines that were made at the Philadelphia works. The errors of the screws were compensated by the indices.

When finally we were prepared to adjust gauging implements there

arose another impediment, more formidable still. The contact points of the calipers with flat faces could not be ground parallel. The grinding wheels have to rotate parallel to these faces, and pass over them, and as the pressure is as the area in contact, the unavoidable elasticity in the wheels and their mountings, produced a curved surface. Here was an inherent principle involved—an insuperable difficulty that seemed to set at defiance all known methods of manipulation.

I remembered then Prof. Sweet's significant remark, and we applied to him for information. It was as expected. This was the difficulty he had met with. He kindly came to Philadelphia to aid us with his own experience and suggestions, but there seemed no way out of this dilemma until one day light came from an unexpected quarter.

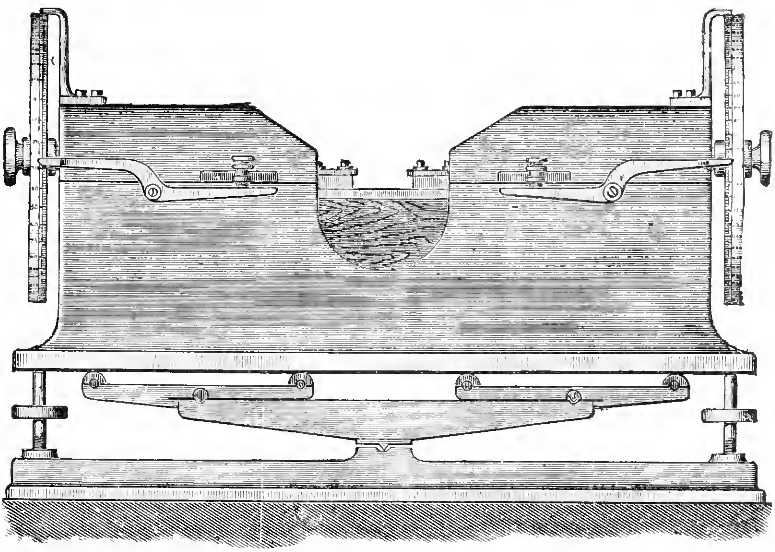

Fig. 2.

Mr. J. Morton Poole, Sr., of Messrs. Poole & Sons, Wilmington, Del., came into the works to examine the gauge-making processes. At that time I imagine that no one in the world had given so much attention to abrasive grinding as Mr. Poole. He had a laboratory for experiments and the making of grinding wheels. He had collected corundum and other abrasive minerals from all parts of the world, and had an organized and classified cabinet of such minerals. We thought then, and I believe yet, that in that laboratory was collected more knowledge of abrasive grinding material and processes than existed among all the makers of grinding wheels in this country, or in the world perhaps. Some of his grinding operations on paper calendering rollers were mar-

velous, and so intricate as to almost defy explanation. He would grind piles of these rollers eleven in height so as to exclude light between them, and the line of light, as it is called, is commonly estimated at the ten thousandth part of an inch. The guidance to produce this marvelous parallelism and truth was derived from what may be called a theoretical axis of rotation, and not from mechanical guides or ways.

Mr. Poole heard patiently an account of our dilemma, and then quietly remarked: "You must grind without pressure; come to Wilmington, and I will show you how to do this."

He had by the selection of certain fine grades of sharp corundum, and by certain methods of cementing, produced wheels that when flooded with a solvent of this cementing material would grind without pressure. I do not now remember the composition, and if I did would not feel at liberty to make it known even at this time.

The theory, as explained by Mr. Poole, was this: "A new sharp edge does not repel, on the contrary will draw the material to the edge. Now each time one of my wheels turns around a new set of edges are brought to bear, because the wheels are slowly but continually being dissolved by the liquid solution in which they run, or with which they are flooded."

The result was remarkable, and will also seem incredible. If a file was laid in front of one of these wheels, pivoted at its center so as to swing against the wheel, and a jet of the solvent solution was turned on, the file when swung against the wheel would remain there, and be ground away without any extraneous pres-ure whatever. This may arise from the effect produced by the liquid, or other cause than the extreme sharpness of abrasive edges. I do not claim to understand the phenomena, and we were too gratified at the results to press for explanations from Mr. Poole. He prepared wheels suitable for grinding the points of calipers, a thing he had never done before for any one, and extended many courtesies and kind acts that will never be forgotten.

The problem of making fixed calipers was solved, and gauge making rendered possible; first, by Prof. John E. Sweet, who discovered and pointed out the nature of the difficulty in grinding the contact points, and by J. Morton Poole, who removed this difficulty by his knowledge of abrasive processes, and it affords me pleasure to present these facts again, nearly twenty years after their occurrence.

As soon as accurate calipers could be ground, orders were taken and the business began, one of the first orders being for a railway works in England, and the second for the Baldwin Locomotive Works, at Philadelphia. It was sixteen years from the time of making the first set of calipers at Columbus, Ohio, and $18,000 had been spent in implements, experiments and other expense.

After the business was founded, some other firms at the East took it up, and added what Mr. Taylor called the "theatrical part." The Whitworth system of end contact or touch, as it may be called, was disparaged, and apparatus for visual divisions was instituted. So eminent a mechanic as Prof. Rogers, of Cambridge University, went so far as to forget the courtesy due to Sir Joseph Whitworth and to deride his "millionth measuring machine."

Sir Joseph Whitworth had made in his works a machine fitted with such accuracy that it would indicate movement to one millionth part of an inch, a thing easily proved and performed hundreds of times, but it was not a measuring machine in the sense of testing or defining dimensions.

I know more of this machine, which I have often seen, than it was possible for Prof. Rogers to learn then or now. It was made mainly by Mr. John Sincock, now of Birmingham, who was for many years in the works of Sir Joseph Whitworth, engaged in the gauge-making department, and who has informed me of the methods of attaining the extraordinary fitting done on this plain-looking machine.

A small bar of metal was poised like a scale beam to vibrate between the contact points of the machine. This bar was set in vibration and the points closed until the friction between them would cause the vibrations to cease. Then the pivots were drawn back, the beam set in vibration and the points returned to within one millionth of an inch of their former position and the beam again set in vibration, which would continue until the points were advanced a millionth part of an inch, when the friction would arrest vibration. The machine is in the Kensington Museum, at London, and is no doubt capable of the same demonstration now. The purpose of the machine, and its only purpose, was to show that surfaces can be so accurately fitted as not to move in stages when such minute adjustment is made.

The standard machine at the American Standard Gauge Works shown in Fig. 2, that weighs about 600 pounds, and has a range of six inches, is fully sensitive to the fifty thousandth part of an inch, as was demonstrated before the Franklin Institute in 1879, when I read the paper before referred to, illustrated by various implements and machines supplied from the gauge works in Philadelphia.

The machine is set on balance beams, a necessity discovered in its adjustment. It is covered with a close glazed case, and set where the sun will not shine upon it. This latter matter caused some difficulty during adjustment. The contact points are double, and it was discovered that during the forenoon the rear points facing southeast were loose, and front points were closer. In the afternoon they resumed their normal relation. This was caused by the sun shining through a window at the back of the machine, and is not a matter of wonder at all.

It is a common supposition that the processes of gauge-making require greât dexterity and skill, because of minute dimensions dealt with, but in a gauge works there is no more care or concern respecting a ten thousandth of an inch than there is over one hundredth of an inch in common fitting. Workmen deal with these small quantities in the most common-place manner, by numerals which represent thousandths of an inch or tenths of thousandths, these being the units employed for all kinds of work.

To show that our ideas of accuracy are relative only. I once employed a wood turner from the country to turn wooden vice screws. The heads were about four inches diameter, but these began to increase because of wear in a notched piece of board he employed for calipering. He was requested to turn the heads one eighth of an inch less in diameter so that they would fit into the screw-cutting machine. He stopped his lathe, and with an appealing look said, "Mister, put that in quarters, I never come down to eighths." In evidence of this he showed us his home-made rule, that was divided only to quarters of an inch. That same man might have been taught in a week to deal with ten thousandths of an inch.

Nearly all finishing operations in gauge-making are performed by succession so as to avoid a rise or change of temperature. If calipers are to be ground, from five to twenty-five are taken at one time, and after a few passes in the grinding machines one is removed and another inserted until a close limit of accuracy is attained. Then the whole are tested by the standards. Each piece after testing is marked with chalk, 2—3—4, and so on, these figures meaning tenths of thousandths of variation from the standards. Those coming within one five thousandth of an inch were taken out as one class and the rest returned to the grinding room.

By repeated trials the accuracy would increase, and a second class within one ten thousandth of an inch would be taken out as completed. A still higher class had a limit of one twenty-five thousandth part of an inch. This was the ultimate accuracy aimed at in commercial implements. These latter were sold at a much higher price, and were seldom wanted. The expense of adjustment increases very rapidly with the precision attained, much faster indeed than the difference in price, and gauges beyond the limit of one ten thousandth of an inch were not very profitable to make.

You will no doubt wonder how such implements can be removed from a machine and be replaced again so as to have precisely the same position, but this is simple enough. Everything ground is mounted on centers or points like those of a lathe, but very carefully prepared and the center points accurate and kept clean. The centering points are cut away from the gauges.

Fig. 3 shows a common exterior or caliper gauge of the standard form.

The first use of gauging implements in a systematic way was no doubt by John G. Bodmer, at Manchester, England. Mr. Bodmer was a Swiss engineer, who, in his day, was one of the foremost mechanical engineers in Europe. He was born at Zurich, in 1786, and, when young, began his career as a millwright, that term meaning then, a constructor of all kinds of machinery. He made his way into Germany and Russia, where he held honorable commissions, and in 1833 went to Manchester, where he founded a machine works, invented and constructed nearly all kinds of machine tools known to modern practice.

I will read a short extract from a memoir of Bodmer, in the minutes of the Institution of Civil Engineers, London, dated 1868:

Mr. Bodmer approved so highly of the French metrical system of

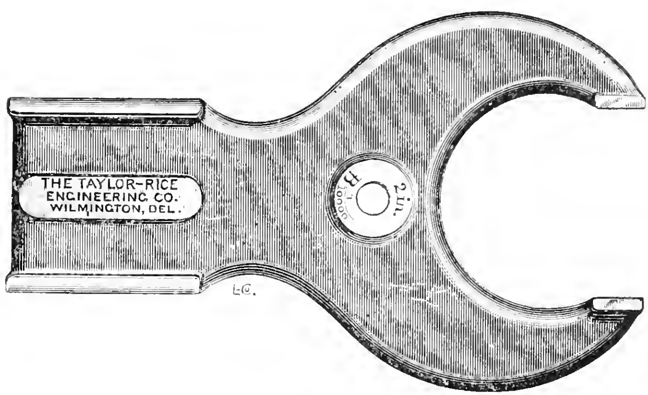

FIG. 3.

measures that he adopted it, and made use of it in all his drawings and constructions. He also, from the first, introduced it into his workshops in England; and so far from experiencing any difficulties in this matter, on the part of the men, they understood it immediately, and liked it, at least, as much as the duodecimal system represented by the old foot-rule, and the subdivision of the inch into "eighths," "sixteenths," and "thirty-seconds." A number of wooden staves of half a meter in length, accurately marked and divided, by a machine made expressly for that purpose, into decimeters, centimeters and millimeters, were distributed amongst the workmen; and although they would frequently, by way of abbreviation, call a "millimeter" a "meter," the misnomer did not lead to any errors. For the use of the pattern-makers, the measuring staves were divided so as to include an allowance for the contraction of the metal, that allowance never being left dependent upon the private judg-

ment of the men. Besides, there was in existence, and accessible to the workmen on application to the foreman, *a complete system of distinctly marked and accurately executed internal and external gauges of various kinds*, so that any required measure could be tested, either directly, or by means of the calipers, if required.

It is more than probable that Sir Joseph Whitworth's pin and collar gauges have this origin. He was then a young mechanic of Manchester, and must have known of, if he did not see, Mr. Bodmer's gauges, but such fact should not detract from the important service rendered by him to constructive mechanical and engineering processes. In all practical views of the matter he gave to the world accurate implements for machine fitting and, it may be said, accurate methods generally.

ECONOMY IN COMBUSTION AND SMOKE PREVENTION.

I. From a Chemical Point of View.

BY DR. C. F. MABERY, MEMBER OF THE CIVIL ENGINEERS' CLUB OF CLEVELAND.

[Presented before the Club, April 14, 1896.*]

THIS club is so accustomed to the consideration of original thought in some form that I feel some hesitation in presenting a subject concerning which I have very little to offer that is especially original. I regret further that on account of the pressure of other duties I have not been able to consider the subject as thoroughly as would have been desirable.

In studying the prevention of smoke, it is necessary to begin with the fundamental nature of combustion. In simple terms, combustion is chemical change brought about by the union of chemical elements, with the evolution of energy, usually in the form of heat. The chemical changes, which concern combustion, are produced by the action under suitable conditions of the force known as chemical affinity. If a piece of iron is consumed in the form of rust, it combines with oxygen in a form of combustion. But the process of combustion is not observed because the operation proceeds very slowly. If the same elements were brought together so that they could unite in a short space of time, there would be more energetic action, such as we are accustomed to associate with the phenomena of combustion. Chemical affinity is a form of energy, concerning which there is much yet to be learned. The chemical elements are storehouses of great dormant energy which become sensible under the influence of chemical affinity. The earlier chemists looked upon all matter in the elemental form as containing phlogiston, a substance of negative weight, which we now indicate by the term energy.

In considering the various forms of combustion we must bear in mind the relations of the ordinary combustibles and the supporter of combustion. Ordinary combustibles include coal, wood, charcoal, natural gas, oil, coke, or turf. The supporter of combustion is the oxygen of the atmosphere. The union of other elements, however, in such a way as to unite and develop energy, may be looked upon as a phase of combustion.

The carbon compounds are the least expensive combustibles, and oxygen of the air the cheapest supporter of combustion. If hydrogen and chlorine be brought together under suitable conditions, there would be a great liberation of heat energy; but these substances are too costly to be

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used in ordinary heating operations. The greatest energy and efficiency in combustion is obtained by the union of gases, because the molecules have perfect freedom of motion, and the molecular proportions of the union may be more readily controlled.

In burning two volumes of hydrogen and one volume of oxygen we have the greatest amount of heat that can be developed in ordinary combustion, equivalent to 34,462 kilogram heat units. The molecules of these gases are free to move, and require no expenditure of energy to bring them to the point of ignition, except the small amount of heat due to their specific heats. The efficiency of natural gas as a combustible is due to the same properties, and to the fact that it is composed largely of marsh gas (CH_4). The hydrogen burns first and maintains the temperature necessary for complete combustion of the carbon. The products are water and carbonic dioxide, and the calorific power generated in its combustion is 11,063 kilogram heat units. Wood is the least efficient of the combustibles on account of the great amount of water it contains that must be converted into steam.

Coal, as we know, is composed of carbon, hydro-carbons, sulphur, nitrogen, oxygen and mineral constituents. When marsh gas burns, the hydrogen burns first; then what oxygen remains is taken by the carbon. The same is true in combustion of coal. Soft coal consists to a large extent of volatile matter. All of the hydrogen in the hydro-carbons of the volatile portions burns first; then, if there is a sufficient amount of oxygen, the carbon combined with the hydro-carbons burn; and finally the fixed carbon. In the combustion of coal, carbon forms first carbonic oxide ($C\,O$); then, by further union with oxygen, carbonic dioxide ($C\,O_2$), the ultimate product of combustion. The conversion of carbon into carbonic oxide is attended by the evolution of 5,680 kilogram heat units. From carbonic oxide to carbonic dioxide the heat evolved is equivalent to 2,400 heat units. Dry wood when burned evolves on an average 3,650 heat units, and bituminous coal an average of 7,500 heat units. Anthracite coal evolves considerable more heat energy. There is greater difficulty in obtaining the same efficiency from bituminous coal than from anthracite coal, because of the way in which it burns as above mentioned. It contains such a large proportion of the volatile hydro-carbons that the distillation of those substances must be controlled within the area of combustion. If bituminous coal be fired chiefly from below, so that the air necessary for combustion comes through the grate bars, that portion of the coal on the grate bars will be perfectly consumed; but the portion above, being only partially heated, will be subject to a process of destructive distillation. The volatile portion will be decomposed and soot will escape. Soot, when once formed, cannot be burned economically.

Combustion in ordinary appliances is supported by draught. There must be a sufficient quantity of air introduced into the fire in order to produce complete combustion, and a sufficient excess to produce draught. This necessarily involves considerable waste of heat energy that cannot be avoided. Gases expand approximately thirty-six-hundredths of their volume for every 100° C. increase in temperature, and it is this expansion and consequent lightness that produces draught. For an adequate draught in the production of high pressure steam it is necessary to maintain a temperature equivalent to 400° to 500° F. in the flue. Unfortunately, in many forms of heating appliances, the loss of heat in the flues is greater than economy permits. Regulation of draught and flues should be such that there may not be more loss of heat than is absolutely necessary to maintain the necessary rate of combustion. As everyone knows, the most economical method of heating compartments is to place the heater within the compartment and to make a long connection to the flue. In this way the excess of heat above that required for draught will be dissipated from the connection to the flue. But where heat is to be generated for the development of power a great amount of heat energy must be produced in a limited space of time.

The fundamental principle of complete combustion is that the temperature of all the substances concerned in the change be maintained at the point of ignition. Especially the volatile portions of coal must be maintained at a sufficiently high temperature that they may be completely burned without destructive distillation. How this shall be most economically accomplished under all conditions seems as yet not to have been satisfactorily demonstrated. Many devices have been proposed. A simple method for low pressure steam consists in maintaining a brisk fire in the rear of the grate and adding coal in front where the combustion is more moderate. The products of distillation are carried forward where the temperature is sufficiently high for complete combustion. There is no difficulty in maintaining this condition, so that any grade of coal, with ordinary care, may be fired so as to give its maximum efficiency and prevent the formation of soot. This method evidently depends on faithful and efficient service in firing. Evidently it does not permit of the rapid combustion which is necessary in the production of high pressure steam.

Among the many appliances which have been suggested, the introduction of air in blast is said to effect a high efficiency. There is a stoker now in operation that claims to give an efficiency equivalent to the evaporation of 12 pounds of water for every pound of coal. I believe that anywhere from 5 to 8 pounds of water per pound of coal is considered good practice in the ordinary methods of hand firing.

Another device consists in the introduction of jets of steam. From

experiments now in progress this device seems to be efficient in preventing the formation of soot. Recently I had an opportunity of observing the operation of such an arrangement, where combustion took place on the grate bars in the ordinary way, with a draught door directly in front and jets of steam turned in upon the fuel. The temperature was sufficiently high to decompose the steam and oxidize the volatile hydrocarbon with complete combustion. There was no escape of soot whatever. The quantity of water evaporated by the application of steam in this manner, as shown by tests made by Mr. C. Goffing, was 9.5 pounds for every pound of coal. There is no doubt that the energy lost in the soot that escapes from the chimney is small. It is my impression, however, from what I saw of this application of steam, that it showed a somewhat greater efficiency than the ordinary method of hand firing, although in a test made by Mr. Goffing without steam and with air supplied solely beneath the grate, practically the same efficiency was observed.

Another essential feature in economic combustion consists in regular firing In hand firing, the temperature falls when new coal is thrown into the fire and the efficiency is impeded, especially in the frequent addition of slack coal. The various forms of stokers effect a good purpose in adding coal regularly to the fire without introducing draughts of cold air, and they render the manufacturer independent of neglect on the part of the fireman.

One of the most important problems for the consideration of the present generation is economy in the use of fuel. The great demands on our coal deposits are increasing daily, and at an enormous rate. Within the last five years we have seen the source of great energy transferred from the fields to the coal mines. In replacing the labor of 250,000 horses by electricity generated from coal, the demand for 40,000,000 bushels of grain besides the corresponding consumption of hay has ceased. Instead of generating in part the energy we expend, we have ceased to be producers and are extravagant consumers of energy that required millions of years for its accumulation; and when it is exhausted it cannot be replaced, at least in such convenient form. Ten years ago an eminent authority remarked that the coal deposits should outlast the present civilization. I wonder if he holds the same opinion to-day.

Perhaps of minor importance to the economy of combustion, but closely concerned with the comfort and convenience of those who live within reach of the soft coal belts, is the prevention of soot. Few people are aware of the expense and destruction occasioned by the immense amounts of soot turned into the atmosphere from the use of soft coal. I am informed on good authority that in one of the principal hotels in this city the soot in the atmosphere causes an actual loss

equivalent to $5,000 a year, and this is only one establishment. Do we think of the enormous amount of sulphuric acid formed by the combustion of coal which is turned into the atmosphere which we breathe? Probably 1 per cent., or 20 pounds to the ton, would be a moderate estimate of the amount of sulphur contained in ordinary coal. A bin containing 15 tons of coal contains 300 pounds of sulphur, which is equivalent to more than 900 pounds of sulphuric acid. Even such amounts in a normal atmosphere would probably not cause deleterious effect; but when the sulphuric acid escapes with soot, the soot absorbs it and it is harmful to fabrics, books, and papers.

In any manufactory true economy depends upon close control of the operation of the furnaces, but this is impossible with ordinary hand firing. An excellent means of control over combustion is obtained by connecting the smoke stack by means of a pipe with the chemical laboratory, so that samples of the flue gases may be collected at any time for analysis. When the fireman knows that the operation of his fires is under constant supervision he will attend more closely to his duty.

When coal is cheap it requires less skill to burn it than to control combustion in obtaining the heat energy desired. In all cases the composition of the coal should be known, as well as the quantity of heat lost in the stack and the composition of the flue gases. I have been impressed by the close agreements of results that were obtained in the examinations of the composition of flue gases. Last autumn I had occasion to make an examination of flue gases from a stoker under conditions where a large excess of air was used, and it is interesting to compare these results with others recently obtained by two of our Seniors in the chemical laboratory, in the stack of a boiler where steam jets are employed. The results are as follows:

STOKER.		STEAM JETS.	
CO_2	7.00	CO_2	7.20
O	16.00	O	14.90
N	77.00	N	77.80

With the above-mentioned details in hand there should be complete control in methods of combustion, and the economy would doubtless be greatly increased. But with the present low prices of fuel, it is doubtful whether any changes relative to the prevention of soot will be possible unless made compulsory by law. It seems unfortunate that the law relating to the prevention of smoke in this city was recently pronounced of no effect.

II. From a Mechanical Standpoint.

By Prof. C. H. Benjamin, Member of the Civil Engineers' Club of Cleveland.

[Presented before the Club, April 14, 1896.*]

Prof. Benjamin.—Prof. Mabery has shown you what are the requirements for complete combustion, and it remains for me to show some of the means that have already been used to bring about that result, and also to point out some of the requirements of a good smoke preventer. Prevention is always better than cure. The only true way to treat such an evil is to prevent it.

Quite a number of experiments were made several years ago on very black, dense smoke. It was all collected and the amount of solid matter was determined by weight. It was found to be in all one-third of one per cent, or $\frac{1}{300}$ of the weight of coal burned in that time. Probably one half of this solid matter was carbon, showing that the amount of coal which is actually wasted in soot is $\frac{1}{600}$ part of the coal. This shows that there is no economy in burning smoke, as far as the manufacturer is concerned. It is his neighbor that would profit by the change.

In preventing smoke the principal requirements seem to be:—

1. That the coal shall be evenly heated.
2. That there shall be a free supply of hot air raised to the temperature of combustion.
3. That the volatile matters distilled from the coal shall pass through gases of such temperature that they shall be burned, so it shall be impossible for these gases which distill from the coal to escape by the chimney, or to become cooled after once having been ignited.

The great mistake that many manufacturers have made in trying to invent a smoke preventing device by the introduction of air about the fuel or at the bridge wall is that they have not made their air hot enough. The introduction of cold air is a disadvantage rather than an advantage, as far as preventing smoke is concerned. It will produce smoke where none existed before. There are a number of stokers on the market which, under ordinary conditions, with uniform firing by a careful fireman, will operate to prevent smoke successfully and with good economy. These different types of stokers all have a common principle, that of maintaining the thickness of the fire uniform, and of supplying the air either by means of steam jets or otherwise at a high temperature above the coal, and insuring that all the volatile matter shall pass through a hot place on the way to the chimney.

One of the more common forms of stokers consists of two inclined

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grates, all the gases being obliged to pass over the incandescent coal before escaping into the chimney, and the clinkers being deposited on the bottom.

Another type has a coking plate at the upper end, and one inclined grate running lengthwise of the boiler. Both have shaking grates.

Still another device consists of a traveling grate with an endless chain over two pulleys and a coking course at the front end, the gas passing over the incandescent coal on the way to the boiler.

There is an underfed stoker, where the coal is placed in the ash pit and forced up through the grate, this being the same as our ordinary base burner, only the other side up.

One other type is the so-called down draught furnace, which is not a mechanical stoker, in one sense of the word, but consists of a water grate connected to the bottom of the boiler by risers, at the rear usually having a drum at the connecting point, and a supplementary grate underneath on which the half burnt coal is dropped and the combustion completed. Most of the air is obliged to pass over the grate down through the fuel, a small amount of air being admitted underneath. The principle of all these is the same, that of supplying air at a high temperature and forcing the volatile matter to pass over incandescent fuel.

I presume there are other varieties that will work under ordinary circumstances with good results, and give good economy. The steam jet is applicable to all of these, and is used in many of them as a means of introducing air at a high temperature.

The great difficulty with all mechanical stokers is the fact that in many establishments there are very sudden demands for steam pressure, and there is a possibility of its being necessary to double the amount of steam used inside of fifteen minutes or a half an hour. Many stokers are not adapted to that kind of treatment. This is one reason why they have failed of adoption. A stoker can not respond so readily to a sudden demand for more steam. I will say, without prejudicing any of the other stokers, that the down draught furnace is the most successful stoker for all such emergencies. It involves the use of hand firing, the coal being fed to the grate the same as to any grate. It allows the same treatment as the ordinary open grate, and the fireman has the same liberty that he would have on any grate. In a paper read by two experts, of St. Louis, last year, it was stated that in their opinion this form of grate was best adapted to cases where there were sudden demands for large amounts of steam, and great fluctuation of the pressure and consumption of steam. They said that this form of grate had done a great deal to diminish the amount of smoke made in St. Louis, where they are more unfavorably situated than we, because they do not get as good coal.

I will mention what seems to me to be the requirements of a good smoke preventing device:—

In the first place, variable feed. It is necessary that it should be possible to vary the feed of the stoker quickly and conveniently. In the second place, it is necessary that the spacing of the grate bars should be variable; that the air spaces between the bars may be varied, and the coarseness or fineness of the grate may be quickly adapted to the particular kind of coal used. Third, it is necessary that the grate bars should be of the automatic shaking type, so as to prevent the formation of clinkers and facilitate the dropping of the ash. Some form of air control is quite important. Almost any form of stoker or grate under hard service needs a high chimney. The great difficulty in many of our establishments is that the chimney is not high enough and the draught not powerful enough. There should be a margin, and the fireman should have the means of controlling it. If there is not enough draught, the fireman can not do anything; if there is too much he can easily reduce it. It is impossible to get good results with a small grate. A grate which is large enough under ordinary conditions is not large enough under sudden emergencies. In order that a stoker may commend itself to a purchaser, it should be easily accessible for cleaning and repairing, and it should be so located that it can be taken out and replaced without tearing out the whole front of the boiler. This is one of the serious objections to several forms of stokers which otherwise are very desirable. Where the feed water is pure, the water grate is a success, and where the feed water is impure, the water grate is not a success. Among the requirements in smoke prevention no item is of such importance as good firing. A good fireman can, with an ordinary grate, give good economy, and to a large extent prevent the formation of the smoke, if the boiler is not forced beyond its capacity. A good fireman is just as necessary with any form of stoker that has ever been used. The reason why so many chimneys smoke is partly because there is not enough fireman and also because there is not enough boiler.

It has been claimed by opponents to mechanical stokers, or to any form of furnace which is intended to prevent the formation of smoke, that it is impossible to realize the full duty of a boiler when equipped with such a device. I know from my own experience that that is not true. I have made experiments with one form of stoker, and continued them for several years. I found it entirely feasible to double the rated capacity of the ordinary return tubular boiler without the formation of smoke. Of course, when the fire is being cleaned, there is a little smoke. But during ordinary combustion there is no smoke except the blue smoke, which is due to impurities. It is possible to double the ordinary rating of the boiler without smoke, with an ordinary mechanical stoker,

and to expect more than this is unreasonable. With hand firing you can not go beyond this without making smoke and without limiting the life of the boiler. It has been found by repeated experiments that such attempts are made at the expense of the boiler.

Summing up then, I will say, the principal requirements for the prevention of smoke are the adoption of a device which shall best be adapted to the particular situation ; second, a chimney of suitable size and height; third, a boiler which is at least half as big as it ought to be; and last but not least, a fireman who is worth more than $1.50 a day.

DISCUSSION.

MR. GOFFING.—I was called to The Hollenden when some of these tests were made with steam jets to determine whether the device detracted from the efficiency of the boiler, the evaporation, or the horse-power. I found that it made no material change. The evaporation and horse-power were very nearly the same. In that particular case the horse-power, with the jets off, figured from the water evaporated, was a little greater, and this was probably due to the fact that the boilers were run a little harder, and that a little more power was used that day. Probably under different conditions the same test would have shown different results. Practically no smoke was emitted when the jets were used, but the next day, when tried without the jets, there was a big volume of smoke from the chimney. As far as the other smoke burning devices are concerned, I would repeat what Prof. Benjamin just said, that with a skillful fireman much smoke can be prevented. Care must be taken to feed the coal properly, and in the proper amount, and the boiler must be such that it will not be necessary to force it beyond its capacity.

MR. WILLIAM H. SEARLES.—The experiments spoken of in The Hollenden Hotel remind me of some tests which I made some seven years ago at the instance of Mr. Holden, of the same hotel. A man had been permitted to put in a device for preventing smoke, which among other things used steam jets. I think he made the claim of from 25 to 30 per cent. saving of coal. The tests were made to verify his claim.

The arrangement was that for twenty-four hours continuously the furnace should be run by this inventor with his apparatus, he managing it himself, and for the next twenty-four hours I should run it without his invention. It was very carefully carried out, all of the water being very carefully measured, the coal weighed, an account of the amount of ash taken and the temperature, etc. I have not the papers with me to-night, but I recollect the result in a general way. The steam generated was used in the hotel

for mechanical purposes, they had the ordinary run of business and no special effort was made either to force the fire or to go below the usual rate. When we got through there seemed to be a very slight advantage mechanically in the device, and yet, after making an allowance for the amount of steam wasted in the jets, the two tests seemed to very nearly balance. The difference was so slight that it was felt that if the experiment were continued for a week possibly the advantage might be on the other side. The inventor's claim was not made good and the device was not adopted; history repeats itself in the recent tests by Mr. Goffing. The steam jet does prevent smoke escaping from the chimney. It does not increase the expenditure of coal, nor on the other hand does it produce any great increase of economy. There is the advantage of a clean draught. During the days of this competition when the furnace was fired without the steam jets there was some escape of smoke from the chimney, but nothing that would be considered in any sense sufficient to warrant complaint in comparison with other chimneys in the neighborhood. Careful firing, and the regulation of draught produce all the necessary steam without any great display of smoke.

Nevertheless, I am in favor of some form of mechanical stoker; these devices are a great improvement over hand-firing.

Mr. N. P. Bowler.—I have been in the business of burning coal a great many years, and I have tried a great many devices. The first device was the steam jet, we did not think it was worth keeping, and abandoned it. We have a large boiler with a small engine and a good engineer for firing. He is capable of firing so as not to make enough smoke to annoy the neighbors. He keeps the live coal back and fires in front; and being very quick in firing, very little cold air goes in under the boiler. We are in favor of a large amount of grate surface, and a large space between bars.

We have not tried any of the other stokers. We have examined them and think some are very good devices. I am in favor of using them, but my opinion is that they do not require as good a fireman as is required without a stoker. Inability to get up a high heat in a short time is true of all mechanical stokers so far as I know. Manufacturers would use automatic stokers if they would accomplish that purpose.

Mr. S. T. Wellman.—I agree with my friend Mr. Bowler that it does not take so skillful a man to fire with an automatic stoker as it does for hand firing. To obtain the best results by the latter method is, I think, one of the most skillful manual operations. Of course, in mechanical stokers the machinery must be looked after, but a man with good common sense can look after that part for a great many boilers. I think the principal cause of incomplete combustion, and of the large amount of soot coming out of our furnaces, is the fact that almost invari-

ably the boilers are not large enough for the work, and the furnace is overcrowded. In mechanical stoking you get the best results and the amount of steam required is regulated. With intermittent firing the best results can not be obtained.

PROF. BENJAMIN.—I would like to say a word or two more about some points in the stoker. The application of steam jets, if not overdone, I have found valuable. But there is a tendency to use too much steam. The direction of the steam jets must be very carefully looked to. If they impinge on the boiler or on the grate, there is danger of injury. I have seen instances when the fire was smoking below and the steam jets were turned on, the smoke was cut off as if cut with a knife. One great advantage of the mechanical stoker consists in the fact that if it is provided with a hopper the inrush of cold air over the grate is effectually prevented, whereas in any form of hand firing when the doors are open, if only for an instant, smoke is formed. A sudden draught of cold air is also one of the most potent means of destruction for the boiler, and is liable to make itself felt very suddenly when you least expect it.

With regard to the skill required in manipulating the stoker, it is a different kind of skill from that required in handling the shovel. It requires more mechanical ability. Another advantage of the mechanical stoker is that one man can attend to more boilers in a given time. If the stoker works as it should, I think a boy could run it. But unfortunately stokers have their ups and downs. If your coal dealer should impose upon your good nature and send you a few carloads of bad coal, you will find that you need a skillful fireman to keep your stoker in order for the next two or three days. These are the times when you need a $3 a day fireman.

MR. BOWLER.—Do you not think the use of steam jets has a good deal to do with hiding the appearance of smoke and covering up the soot?

PROF. BENJAMIN.—I think the action of the steam jet in the first place, is to introduce air at a high temperature where it is needed. Nearly all the devices which use steam jets have an air draught back of the jet so the air is heated by the steam and applied where it is needed to further combustion. Further than that, I believe that steam decomposes and furnishes additional oxygen where it is needed.

MR. OLDHAM.—I think the great cause of smoke is want of oxygen. If I remember rightly, for every pound of coal consumed 100 cubic feet of atmospheric air is required; 20 cubic feet of oxygen is required for the combustion of a pound of coal. Dr. Mabery said that the air should be heated, and that is the great secret of perfect combustion. A gentleman in Glasgow, whose name I can not at this moment recall, has gone thoroughly into the subject, and has brought combustion to 40 pounds per square foot of grate. Frequently this can be done without

injury to the boiler and it is accomplished by hot air. The average combustion of coal is 16 pounds per square foot.

As regards soot accumulating, I want to show you how injurious it is. It has been found that a thin coating of soot will prevent the heating of water just as much as a $\frac{3}{8}$-inch plate placed alongside of the furnace. Soot is a serious non-conductor. Where you adopt forced draught you can increase your consumption to an unlimited extent.

I am surprised that the mechanical stokers are not more used. They were used at sea twenty years ago, and distributed the coal very evenly over the fire. I should strongly recommend the adoption of the mechanical stoker. If boilers had more diameter and more heating surface, they would find great economy in the prevention of soot accumulating on the boiler. It is almost equal to the precipitation of lime and other ingredients from water on the inside of the boiler. My advice is to adopt the best mechanical stoker, increase the size of boilers, and add air draughts.

Mr. A. H. Porter.—I would like to ask Dr. Mabery a question. Does the condition of the fire have much to do with making the steam jet a satisfactory and successful smoke consumer? Is it as efficient with a slow as with a hot fire? I ask this question because I have seen statements that water is not decomposed into its elements with a heat less intense than that of a blast furnace, while the heat in most combustion chambers is very much less intense than this; hence the water is not decomposed, but the steam is simply carried up the stack as superheated steam, and has contributed nothing chemically towards consuming the gases of the furnace, its good effect being mechanical, simply forcing the draught. Instead of adding to the heat units of the fuel, it has actually taken from them sufficient to superheat the steam itself. I remember hearing one of our former Presidents state that the smoke was simply washed or painted by the steam jet, not consumed.

Dr. Mabery.—I have had very little experience with the application of steam, except in this particular instance at The Hollenden. It seems to me that the temperature was sufficiently high for the decomposition of steam, and possibly that aided combustion. Whenever I have heard steam jets recommended, I have always thought of the possibility of a corrosion of the boiler. In ordinary combustion a small amount of sulphuric acid is formed. In the use of steam I think it forms to a greater extent. It has occurred to me that boilers might be corroded by the greater formation of sulphuric acid, but it may be a question whether or not there is a greater amount of sulphuric acid with the use of steam jets.

Mr. Balkwill.—I had occasion to observe a little point at the time this smoke consumption law was agitated. A certain engineer

referred me to the amount of water that came down in his stack and dripped out of the sheet-iron pipe connected with the brick stack. He claimed that the sheet iron was corroded by this water, which was formed by the condensation of the steam before it got out of the brick, stack. He also corroborated Professor Benjamin's statement, claiming that he used to fool the inspectors when they came around. He did not like to use the steam all of the time and provided a valve. When the inspectors came and said that smoke was coming out of his stack, he would ask them to show him where the smoke was. On the way out he would turn the handle of the valve, and there would be no sign of smoke.

Mr. Newman.—It seems to me from the experiments made at The Hollenden that the steam, instead of decomposing under the temperature, tends to deposit the carbon in a manner similar to that of passing smoke through water. It seems very probable to me that the steam would have a tendency to precipitate free carbon suspended in the combustion chamber. In my opinion hand stoking is preferable. If we take away the amount of steam used in the steam jet, the total amount of steam would be less than that obtained by hand stoking.

President Howe.—In times past I have seen large volumes of smoke coming out of the smoke stacks of the Water-works Department. Perhaps Mr. Kingsley can tell us what he has done to prevent it.

Mr. M. W. Kingsley.—If you will observe one of the chimneys, you will see that it is smokeless. We have mechanical stokers under that chimney. The other chimneys are hand fired. In the last five years we have devoted our attention to American stokers in line with smoke prevention. We have now ten boilers equipped with mechanical stokers, and are advertising for four more. As fast as the old boilers are played out, we are equipping them with new ones, and all the new boilers are equipped with smoke preventing devices.

In regard to steam jets we have tried them in times past and we have never made a success of them in our boilers. There is but little difference in the evaporation between good hand firing and mechanical stokers.

STEAM ENGINES FOR DIRECT CONNECTED ELECTRIC GENERATORS.

By E. A. Sperry, Member of the Engineers' Club of Cleveland.

[Read before the Club, May 12, 1896.*]

For the past fifteen years the subject of adapting the steam engine to the direct driving of high-speed machinery, especially of electric generators, has been one of growing importance. It was early seen that gearing and other speed-multiplying transmission of one form or another was unsatisfactory for large units, especially in lighting, and attempts were made to perfect engine designs so as to make them conform to the high-speed requirements, this seeming to be the basal proposition in the early history of this branch of the art. Later, large belt-driven units were looked upon with greater favor. In the early days of electric railroading the use of the belt-driven generator and the multiplication of smaller units were in general use. This, however, has given way to a growing preference for direct-driven generators of moderate and even low speed, with direct coupling to engines of the Corliss type, making as low as 60 and 80 turns per minute.

While this construction is found to solve many of the difficulties of the power station and to effect economies in space, efficiency, etc., it entails a heavy outlay in the cost of the manufacture of the generator itself, amounting, in many instances, to twice, or more than twice, the cost of the driving engine, even though the latter be a multi-cylinder compound condensing machine. The design of the direct-driven plant under discussion has for its object the material reduction and even halving of the first cost of the generator, which is the largest single item of expense in the installation.

Speed-multiplying power-transmission is effective in accomplishing this end, but it has its limitation, and, even in the kindred arts, it has been found to be undesirable. Within the period of which we are speaking, a change, which constitutes almost a revolution, has been worked in this branch of engineering. In nearly all the large cable stations we have seen gearing displaced by belting and rope transmission. The same thing is true of many of the mills in New England, and in all the most notable recent factory installations we have seen each line shaft, and even each tool, "direct driven."

The growing prevalence of extremely low speeds for direct driven work is considered by many to be a direct acknowledgment of the superior economies attained by the class of engines operated by valves,

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known as "Corliss." Direct acting valves are preferred by some engineers, but the Corliss valve has many followers. Owing to its cycle of operation, this valve has a serious limitation as to speed. Doubtless this can be largely increased over the present practice by the employment of aluminum at certain critical points. The inertia of at least two portions, forming essential parts of each valve, could in this way be reduced to practically one-third of its present value, and these parts, which are compelled to obey the law of falling bodies in their normal action, could thus be made to perform their functions in far less time and at a greater actual speed. In this way it has been found that the present limitation of speed of the Corliss engine—from 90 to 110—can be increased before the limits of certainty of operation is reached.

While the Corliss valve gear may be the preferred form adapted to the plant and coupling under discussion, the coupling is by no means limited to this style of valve, but is equally adapted to any of the practical and successful types of valve and valve-operating mechanism.

Turning now to the special features of the new design, its operation may be briefly indicated, by reference to the accompanying figures illustrating a 22″ x 34″-32″ stroke engine. The power arriving at the cross-head is transmitted by a short pitman to a divided lever, fulcrumed at the gudgeons seen in line with the horizontal pitman. The lever is provided with a counterweight to the right of the gudgeons and the parts of the lever are sometimes united by a bridge just above the gudgeons. The free end of this lever is connected with the pitman by a swinging link, which is about the same length as the lever, and is also preferably of divided form. At the point of union between the link and pitman a guide is provided which may work in slides, but preferably as shown upon the upright swinging arm which extends from this point down to the left side of the body of the foundation through a recess to a sole plate where it is suitably journalled. This sole plate is connected in turn with the bed plate of the engine by bolts which are clearly indicated by dotted lines. The engine is shown in the uppermost point in the stroke of its piston, and in descending swings the lever about its gudgeon to an equal angle below the pitman also indicated in dotted lines. In its descending stroke it will be seen that the pitman is given a double oscillation, to the left during the first half, and to the right during the last half of the downward stroke of the piston. These strokes are again repeated, in order, on the full upward stroke of the piston. Thus it will be seen that an entire revolution of the crank shaft requires but a single stroke of the piston rather than a double stroke as with the ordinary connection. In other words, the *speed of rotation of the crank shaft is doubled.*

If this engine piston therefore were given 110 full reciprocations

we would have 220 revolutions of the crank shaft; or if given 140, then 280 equals the crank shaft speed. This is seen to be a high velocity for an engine provided with Corliss valves, and at the same time the piston speed is kept at a comparatively low point. The upright swinging arm extending upward from the lower portion of the foundation may be utilized to operate the condenser pump and also an oil system for all the running parts of the engine. The oil naturally collecting at this lowest point in the system, the sole plate is provided with oil-retaining walls so that the pivot of the swinging arm always stands in oil.

By varying the point upon the lever by which it is attached to the cross-head, the stroke of the piston and pitman may be held on quality or may be made to vary in any desired ratio to each other. When these ratios are equal, the strength of the parts, for instance the crank shaft, pillow-block, crank-pin, pitman, etc., need not be materially altered from the best practice in the ordinary type of engine. This, it will be readily understood, would not be the case if, for instance, the piston were attached to the oscillating links at their articulating point. In this case the strokes of the pitman for anything like the best distribution of strains would have to be far less than the length of the stroke of the piston, and would therefore have to be made very much heavier for an engine of a given piston speed; furthermore, this piston speed, which is by far the greatest limitation in present engines, would in no wise be overcome, but would on the other hand be aggravated. The attachment of the piston at a point on the lever intermediate between the fulcrum and the articulating point, or any method with the arrangement shown whereby the stroke lengths of the pitman and piston may, if required, be rendered equal and allowed to vary from this point either way, I consider as one of the essential parts of the system.

The upright engine thus produced, considered generally, is of desirable form, owing to the general accessibility of the cylinder and valves from the engine room floor, requiring no stairway and gallery unless tandem construction is employed. The matter of extremely low headroom and freedom from anything resembling top-heaviness is generally conceded to be a point of advantage over the old type, and especially over the simpler forms of upright engines. Moreover, the cylinder is closer to the pillow block both in line of strain and by measurement, and the spread upon the foundation is good. While this is true, all the advantages of the upright engine. such as inexpensive foundation, low cylinder wear, etc., are retained.

Among the other points of value found to exist in the construction may be mentioned briefly the equalization of the crank strains throughout the rotation, together with the opportunity for balancing the weights of the vertical reciprocating and oscillating parts. The crank strain in

the ordinary engine is illustrated in the accompanying diagram, Fig. 4. All parts of the extension of the lever beyond or to the left of the point of attachment of the short pitman, from the cross-head, move at a greater velocity than the piston. This fact offers opportunity for power storage during the accelerating portion of the stroke or *toward* the horizontal center, for use during the last half of the stroke, or the stroke *from* the horizontal center, and the weights of the lever and link especially in this part have been so adjusted by increasing their section that practically a uniform crank effort is secured throughout the piston stroke, as indicated in diagram No. 5. The weight acting with the accelerated velocity is also valuable in lieu of fly-wheel. Owing to the high speed of the crank shaft, the fly-wheel of the engine is in any event a little less than one-half that required in the ordinary construction.

To illustrate the function of the masses and counterweights attached to and forming a part of the oscillating or reciprocating elements let us take a case of a 400 H.P. engine making one hundred double strokes of the piston and 200 revolutions of the crank shaft. The articulating-point between the lever and the link will be found to attain a velocity of about 52 feet per second crossing the center line of its oscillation, that is, in half a stroke it has attained approximately this velocity. It has been found that the weight of vibrating masses should be such that at this central point they will have absorbed in their acceleration a considerable percentage of the energy delivered from the source of power. This in most instances should vary from 30 to 50 per cent. of the power. With high velocities light parts will be found to fulfill these requirements. These percentages may be with advantage increased considerably, but should not be decreased very much below the percentages given, although experience may lead to a wider variation for special purposes.

In the case cited, one ton at this point may be made to absorb 165.6 horse-power seconds. The energy stored in the moving masses up to this point is delivered by them to the pitman and crank-shaft in the last half of the stroke. The increase in weight of the oscillating mass furthermore tends to neutralize the lunge or any tendency to pound and to give a more uniform movement while passing the center of oscillation, at which point the strains are reversed. Both these points have been found essential and necessary in the calculations, not only to smooth running but for economical construction.

Fig. 2 of the diagram indicates the new system of valve distribution for the engine. The valves are two in number instead of one. These are located in the same plane, their axes taking up an angle to each other partially embracing the cylinder for a short portion of its circumference, so that no part of either of the valves is allowed to recede

very far from the bore, giving a very material gain in cylinder clearance, as is made evident by the adjacent diagram showing the old construction.

The prime object sought in the design, viz: the reduction and practically *halving the cost of the direct driven generator*, will be found to be fully accomplished in practice. The following considerations have also been observed. The generator being only one half the size and weight of the former machines, the smaller sizes can be shipped assembled at greatly reduced cost compared with the larger units. Furthermore the reduced weight and greatly reduced number of the crossings required in the copper armature-winding and segments in the commutator give a material saving in the cost of erecting. It is hoped that the simplicity of the design and the double use of the power connection between the piston and the crank, fulfilling in this case the added function of doubling the speed, will offer a new stimulus to the two industries to which it more directly relates, and find a wider application to the art than has been the province of this paper to discuss. In addition to the direct driving of electrical generators it is now being adapted to the direct driving of fans and high speed rolls for sheet mills, and other applications will no doubt be forthcoming.

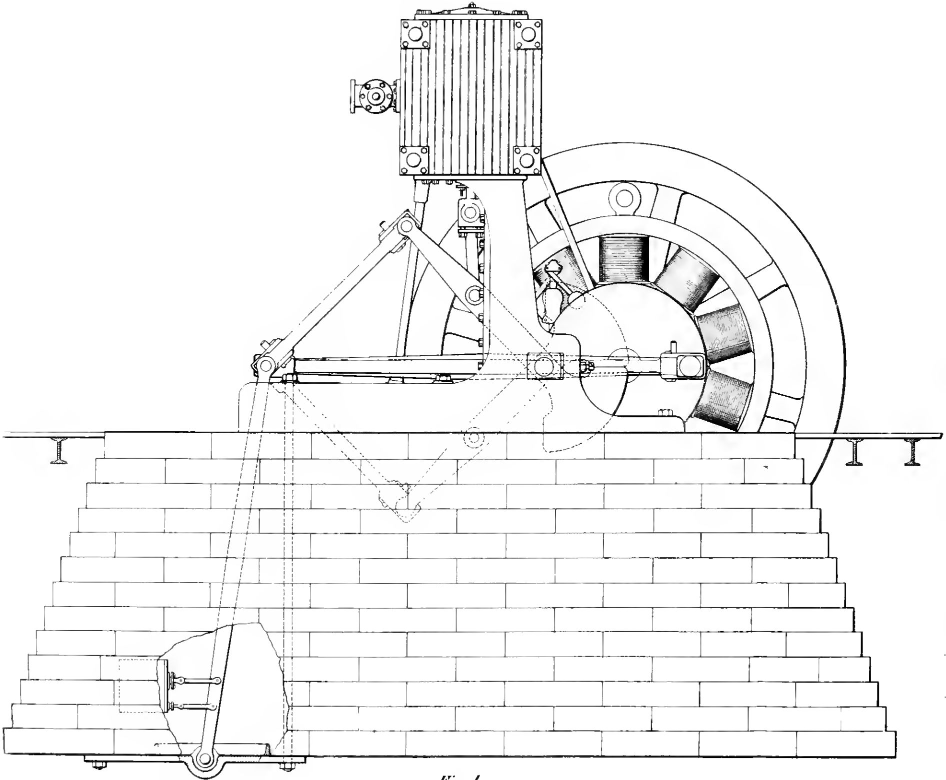

Fig. 1.

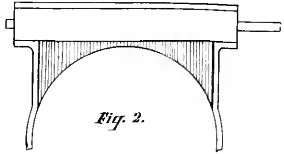

Fig. 2.

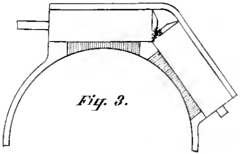

Fig. 3.

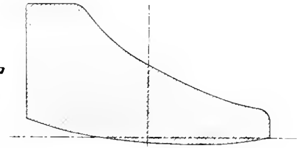

Fig. 4.

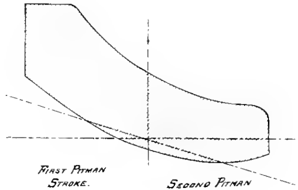

Fig. 5.

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Organized 1881.

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AMERICAN HYDRAULIC GATES, WEIRS AND MOVABLE DAMS.

I. Movable Dams, Sluice and Lock Gates of the Bear-Trap Type.

BY ARCHIBALD O. POWELL, U. S. ASSISTANT ENGINEER, MEMBER OF THE CIVIL ENGINEERS' SOCIETY OF ST. PAUL.

[Read before the Society, October 7, 1895.*]

THE designing and constructing of movable dams, sluice and lock gates has heretofore been largely monopolized by government (National and State) engineers, and it is likely that lock gates and movable dams will continue in their exclusive field, but the utilization of applied electricity in the industrial arts, and the extension of large irrigation projects, by promoting the development of latent water power on the one hand, and the collection and distribution of large volumes of water on the other, will expand the opportunities of the hydraulic engineer in private practice. It is in a measure due to the limited demand, in the past, for suitable gates in private dams that their essential features have not been more widely discussed, but we may expect, in the future, in consequence of the increased number of engineers and builders interested, a development of this important detail in dam construction.

COMPETITORS OF THE BEAR-TRAP SYSTEM.

Before proceeding with a description of bear-trap gates, it may not be amiss to allude briefly to the various forms of gates and movable dams that are the competitors of the bear-trap system.

* Manuscript for this series of papers received from April 25 to May 8, 1896. —*Secretary, Ass'n of Eng. Socs.*

The good types, exclusive of lock gates,* are few and may be classified as follows:

1. Stop-planks.
2. Slide gate or door.
3. Segmental gate.
4. Drum-weir.
5. Poirée frames fitted with needles, stop-planks or doors.
6. Chanoine wickets worked from a maneuvering boat or a bridge of Poirée trestles.
7. Overhead bridge in conjunction with stop-planks, doors or needles.

The first three are sluice gates, the last three are movable dams; the drum-weir, as well as bear-traps, is adapted to either purpose.

Stop-planks were the primitive method of cutting off water, and were used vertically as flat needles in the first movable dams. The cheap and simple construction of horizontal stop planks commend them to the economical engineer. They are still in use, and for narrow openings and moderate heads, where infrequent manipulation is required, they answer the purpose as well as the more expensive constructions.

The common slide gate, or door as it is frequently termed, dates back almost as far as the stop-plank. It would naturally be the next step in the development of gates. Later, when dam building became more of a science, roller bearings were added. The increase in size of the rollers matured in the segmental gate, which may be considered as a sliding door resting on rollers of the same diameter as the hollow cylinder of which the gate is a segment. The Tainter-Parker form is the American type of this class.

Our foreign friends preceded us in the investigation of curved gates, and elaborated a number of deviations. Some of their constructions received the pressure on the concave side; the arms were tension members.

Mr. Thomas Parker, who afterwards produced the Parker improved bear-trap, was the originator of the Tainter-Parker segmental gate. Mr. Tainter purchased Mr. Parker's interest and subsequently (1886) took out a patent on the present form.

It is an excellent gate—strong, safe, reliable and inexpensive, with little liability of getting out of order. All parts are exposed for inspection. By the use of counter-weights, gates 20 feet in length and 16 feet head are handled by one man. For sluices of narrow width, designed

* The various styles of lock gates are omitted as they are not of so general an interest, and their consideration would unnecessarily lengthen this paper.

merely for the discharge of water and where the backwater does not reach to the hinge, we consider the segmental gate equal, if not superior, to all others. It is especially useful in reservoir dams.

Photographs and drawings of these gates, built by Major W. L. Marshall on the Illinois and Mississippi Canal, are published in appendix K. K., Annual Report of the Chief of Engineers, U. S. Army, 1894, and in the *Engineering News*, issue of February 14, 1895. A segmental gate, built by Majors Marshall and Davis, on the Fox River, Wisconsin, is shown opposite page 2,367, Annual Report of Chief of Engineers, Part 3, 1890.

The Poirée frames and Chanoine wickets are of French origin. They are extensively used by European engineers, and have been adopted on important works * in the United States. The conservative engineer will find in them safe and practicable designs which have been thoroughly tried and their excellent qualities demonstrated. The defects as compared with bear-trap gates are: The leakage, the labor and time consumed in operating, and the high cost. For situations where time and labor are not prime factors, the Poirée frame fitted with needles, stop-plank or doors, is satisfactory for movable dams, and the engineer that accepts it, or the Chanoine wickets, need not fear criticism. The Chanoine wickets add to the expense, but they are operated more quickly than a dam of Poirée frames. Both of these types admit of structures of any length, and leave a clear open river when the dam is down. The two systems possess three merits which will commend themselves to thoughtful and careful men: Their adaptation for any length of dam, their immunity from serious derangement by a deposit of sediment, and the facility with which damaged trestles and wickets can be replaced. The sediment in many rivers may decide the character of the dam. The two systems are favorable for a condition of much sediment. If the deposit is not too great, the parts can be loosened and raised; if deep, scraping or shoveling is at first resorted to, and afterward the erected portion utilized to deflect a current that will wash away the remaining deposit.

The overhead bridge is another European design that has been successfully introduced † into this country. Its use is restricted to moderate widths. The bridge is either a fixed or draw span, depending upon whether or not the opening is to be left clear for the passage of high-water craft. The floor of the bridge is a strong truss supporting the upper ends of needles, or posts carrying stop-plank, sliding or swinging doors.

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* Needle Dam—Big Sandy River. Chanoine Wickets—Great Kanawha and Ohio Rivers.

† St. Mary's Falls Canal, Michigan.

PLATE 1.

DRUM WEIRS

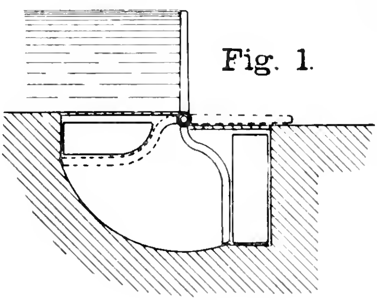

Fig. 1.

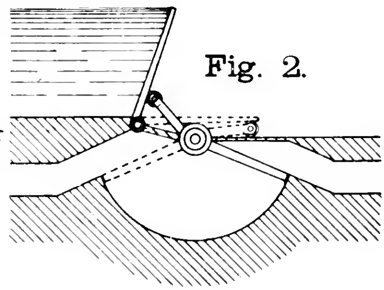

Fig. 2.

DES FONTAINE

CUVINOT

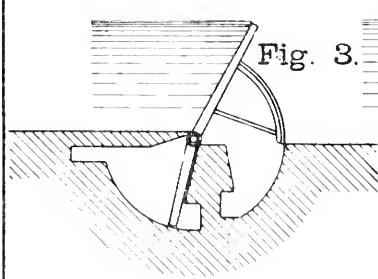

Fig. 3.

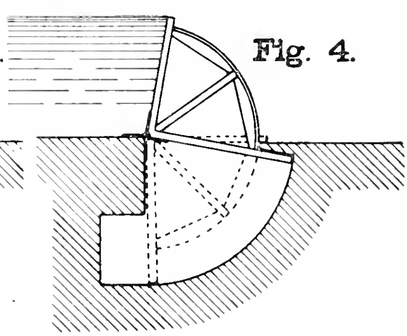

Fig. 4.

CHITTENDEN

The gates and dams thus far described are the devices of the early dam builders perfected by capable men supplied with the materials and workshops of the nineteenth century. They all require the expenditure of extraneous labor in their manipulation.

Repeated attempts have been made to utilize the velocity head of running streams and the static head of dams, to operate the gates, but thus far only two successful types have been evolved. To America belongs the credit of originating the first (bear-trap) and it perhaps stimulated M. Des Fontaines to produce his drum-weir.

The drum-weir is a neat design and theoretically has much to be admired. It has not found favor mainly because of the cost of the well and of the fear that the chamber would prove but a catch-basin for sediment.

There are four forms of this weir known to the writer. They are shown on Plate I. The first was built by the inventor on the Marne; the second was soon afterward proposed by M. Cuvinot; the third was described by Herr Nakong in 1890 *, and the last was proposed by Capt. H. M. Chittenden, Corps of Engineers, U. S. A., in 1895.

The weir is operated by the head of water. The pressure on the lower paddle is regulated by valves in flumes leading up and down stream from the chamber. In Figs. 1 and 4 the lower paddle must be the longer. The designs in Figs. 2 and 3, while more complicated, reduce the length of the lower paddles and, therefore, the depth of the well.

The drum-weir is most applicable to positions on top of fixed dams. In that situation the well is least objectionable and the liability to catch sediment a minimum. The dams erected by M. Des Fontaines are reported to work with ease and celerity.

Its advantage over the bear-trap is: the gate may be made in sections, short or long, without intervening piers; each section may be operated independent of the other; the wells are separated by water-tight partitions. With all its seeming merit and correct theoretical conception engineers may be apt to regard the drum-weir as a delicate and an expensive mechanism. Captain Chittenden's design offers the least objection and is a valuable suggestion.

The reputation of the Poirée, Chanoine and drum-weir constructions have been well earned; they deserve the encomiums expressed by their advocates. M. Malézieux characterizes them as "the three classic systems." The competitors of the bear-trap are indeed formidable and strongly intrenched in the conservative preferences of our brethren in the profession.

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* *Engineering News*, October 18, 1890.

BEAR-TRAP GATES.

We now reach the subject—bear-trap gates—the treatment of which is the purpose of this paper. We do not wish to be understood as advocating bear-traps to the exclusion of the forms just described, for we admit the limitations of each, but are confident that bear-traps are adapted to many cases, that their resurrection through the recent modified and improved forms will be permanent and that in the future they will receive due recognition in engineering literature and works.

The practice in the improvement of United States rivers has been largely borrowed from the Europeans, and it is with pride that we can discuss a meritorious gate and movable dam that is distinctly American.

HISTORY AND DESCRIPTION OF BEAR-TRAP GATES.

The early history of the bear-trap is connected with an interesting chapter in the development of our national industries and resources which we would fain recite in detail. The members of the Society, if they choose, can find lucid descriptions in the histories of Philadelphia and Pennsylvania.

The inception of the bear-trap was an incident in a remarkable enterprise by two notable men—Josiah White and Erskine Hazard. In 1814, they firmly established, by experiments in their wire mill, the value of anthracite coal. That there should have been a doubt about the feasibility of burning hard coal, or any difficulty in the process, seems at this late day quite comical. It was, nevertheless, a fact. In 1817, White and Hazard disposed of their power and plant at the Falls of the Schuylkill, and undertook the task of mining and shipping anthracite coal to Philadelphia. They acquired control of the lands of the Lehigh Coal Mine Company in the vicinity of Mauch Chunk, and obtained from the legislature, in March, 1818, authority to improve the Lehigh River. In July and October following they organized respectively the Lehigh Navigation Company and the Lehigh Coal Company.* It was necessary to create two companies, as most investors were skeptical of success in improving the river. The following graphic accounts of the improvement are quoted:

"The legislature were early aware of the importance of the navigation of the Lehigh, and in 1771 passed a law for its improvement. Subsequent laws for the same object were enacted in 1791, 1794, 1798, 1810, 1814 and 1816. A company was formed under one of them, which expended upwards of thirty thousand dollars in clearing out channels, one of which they attempted to make through the ledge of slate which ex-

*Subsequently (1822) consolidated into The Lehigh Coal and Navigation Company.

tends across the river, about seven miles above Allentown, but they found the slate too hard to pick, and too shelly to blow, and at length they considered it an insuperable obstacle to the completion of the work and relinquished it." *

White and Hazard, as managers of the Lehigh Navigation Company, commenced the successful improvement of the river in August, 1818.

"The improvement consisted, at first, of wing dams, as the company could not then raise a sufficient means for slack-water navigation, and they did not know that the market would take from them a sufficient quantity of coal to justify the expense of a more perfect system of improvement. In their report to the stockholders, December 31, 1818, the managers said that they had 'made dams amounting in length to about 13,000 feet, and supposed to contain upwards of 16,000 perches of stone. By these dams the parts of the lower section that were considered the worst have been made navigable at all seasons of common low water, and a fresh dam, 450 feet long, is nearly finished, which they trust will accommodate the public with navigation to Easton the coming season.' The following year they found that they had been misinformed in regard to the lowest point reached by the river, and that the natural flow of the Lehigh was insufficient to give 18 inches and a width of 25 feet, as was required by law, and hence they were obliged to resort to the plan of producing artificial freshets. For this purpose a peculiar sluice was needed, and Josiah White devoted himself for several weeks to the work of constructing one, finally producing what came to be known as the 'bear-trap.' He built a miniature experimental sluice in Mauch Chunk Creek, about where Concert Hall now stands, and the name 'bear-trap' was given to it by the workmen who were annoyed by the curious as to what they were making.

"During the year 1819, twelve of these dams and locks were built and the managers fully proved their ability to send to the market, by the artificial navigation, such a regular supply of coal as would supply the demand." †

Another historian says:

"The following plan was adopted to render the passage of the river more facile. The obstacles in the bed of the river were removed and thirteen dams, with sluices of various heights, were constructed of pine logs, at an average expense of three thousand dollars each. The gates of the sluice, of a peculiar construction, were invented by Mr. White (to

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* History of Pennsylvania, by W. H. Egle, M.D.

† History of Lehigh and Carbon Counties, Pennsylvania, by Alfred Mathews and Austin N. Hungerford.

whom the company are indebted for many ingenious improvements) and merit particular notice. The gates in the sluice or lock were attached to the flooring by hinges and rose by the force of the water admitted from a *floom*, constructed parallel with the lock and when suspended forming a section of the dam. When the *floom* was closed, the water beneath the gates passed off, and they fell by their own weight, and the pressure of the fluid from the dams. The dam served a double purpose, forming pools of navigable water and reservoirs. At fixed periods the arks were passed with great rapidity through the sluices, and the sudden influx of water gave additional depth and velocity to the streams below."*

Some writers used the words dam, lock and sluice indiscriminately, leaving some doubt as to whether the arks of coal were sometimes locked through the dams or always sluiced over the submerged gates. President Ashbel Welch, of the American Society of Civil Engineers, in his annual address is more clear but probably mistaken in his account of the improvement of the Lehigh:

"The descending navigation they made consisted, first, in clearing the channel of rocks, and confining the water on the rapids, when low, to that narrow channel by boulder wing dams; second, when the fall was too great for this, in building dams with bear-trap locks; and third, in storing the water in pools, and letting it run only when the coal arks were running.

* * * * * * *

"Near each end of the lock was a pair of gates. . . . They could be held in any position so as to hold back the water entirely, or let it run over with more or less volume, as required. The arks containing the coal were commonly shot through over the partly raised gates as over so many dams."†

In response to a recent inquiry by the writer as to whether Mr. White built any locks with bear-trap gates, Mr. C. F. Howell, Auditor of the Lehigh Coal and Navigation Company, replied:

"I am unable to give you drawings of the lock or sluice gate known as the 'Bear-Trap.' . . . In regard to the manner of transportation of the arks of coal in the early days of the company, I find in consulting our early records that the boats were sluiced through the dams and no locks were used. Dams were constructed in the neighborhood of Mauch Chunk, in which were placed sluice gates, by means of which the water could be retained in the pool above until required for use When the dam became full, and the water had run over it long enough

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* History of Northampton, Lehigh, Monroe, Schuylkill and Carbon Counties, Pennsylvania, compiled by I. Daniel Rupp.

† *Transactions, Am. Soc. C. E.*, May, 1882, pp. 169, 170, 171.

PLATE 2.

BEAR TRAP GATES

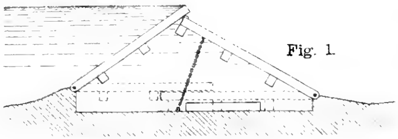

Fig. 1.

OLD BEAR TRAP
DAVIS ISLAND DAM, OHIO RIVER

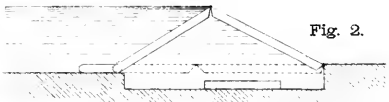

Fig. 2.

DU BOIS' MODIFICATION

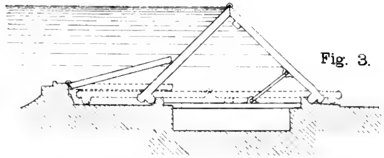

Fig. 3.

CARRO'S MODIFICATION

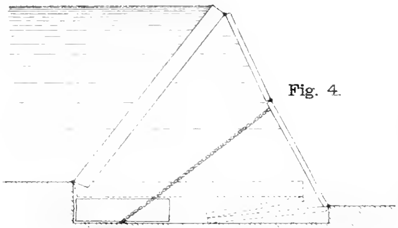

Fig. 4.

GIRARD'S PATENT, 1868

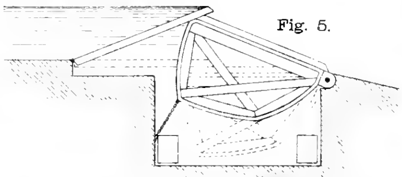

Fig. 5.

BRUNOT'S GATE WITH UP-STREAM APRON

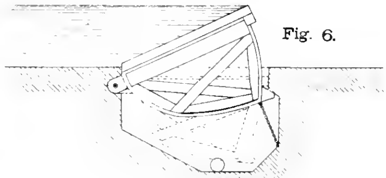

Fig. 6.

BRUNOT'S GATE

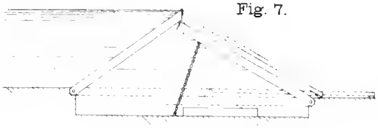

Fig. 7.

OLD BEAR TRAP
WITH DU BOIS' APRON

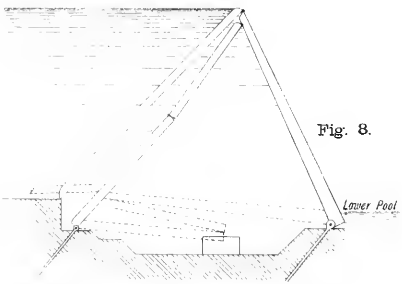

Fig. 8.

PARKER'S IMPROVED BEAR TRAP
MILWAUKEE RIVER DAM, WIS.

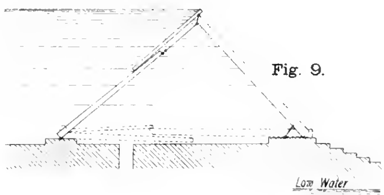

Fig. 9.

LANG'S IMPROVED BEAR TRAP
NEVER'S DAM, ST. CROIX R. WIS.

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† *Transactions, Am. Soc. C. E.*, May, 1882, pp. 169, 170, 171.

for the river below to acquire the depth of the ordinary flow of the river, the sluice gates were let down and the boats (arks) which were lying in the pools above passed down with the artificial flow. About twelve of these dams and sluices were built in 1819."

Mr. Howell's account is the same as that given in Dr. Egle's History of Pennsylvania, where it is further stated that:

" The descending navigation by artificial freshets on the Lehigh is the first on record which was used as a permanent thing."

We cannot refrain from a more extended notice of Josiah White and Erskine Hazard—they were prominent men in their State, of high standing for sagacity and probity as well as for engineering attainments.

" Josiah White's perseverance, pluck, skill and fertility of invention, coupled with great financial ability, were the leading forces [in the operation on the Lehigh and in the coal mines]. He was the pioneer in canal development in Pennsylvania. . . . His name will be inseparably linked with the improvement of the Lehigh, with the building of important railroads, the first successful mining of coal, and its first successful use in the manufacture of iron. . . . He was a man of sterling worth and integrity."

* * * * * * *

" Erskine Hazard was scarcely second to White as a promoter of the several enterprises along the Lehigh. He was a man of great ingenuity." *

White and Hazard built the second tramway and gravity railroad (Mauch Chunk Railroad) constructed in the United States, which was the first road laid out instrumentally and with an even grade. These two men also built the first suspension bridge. †

Subsequent to the use on the Lehigh River of the bear-trap gate, it became more popular on the logging streams of Pennsylvania and in Canada, where it was used as a reservoir and sluice gate for flushing the river by an artificial wave of water on which logs and lumber were carried to market.

The old bear-trap is shown on Plate II, Fig. 1. It consists of two flat rectangular leaves of a length equal to the width of the opening in which they are placed, and having their opposite extremities hinged to the floor at right angles to the direction of the sluice way. The upstream leaf overlaps the downstream leaf. As the gate rises the upstream end of the lower leaf slides (friction is reduced by rollers) outwardly along the under surface of the upper leaf. When up full height

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* History of Lehigh and Carbon Counties, Pennsylvania, by Alfred Mathews and Austin N. Hungerford.

† History of Philadelphia by Scharf & Wescott, Vol. I, p. 584.

a cross-section of the gate is in the shape of a triangle. The total movement of the lower leaf is controlled by cleats or stay chains.

The operation of the gate is effected by the utilization of the mechanical power in the head of water. Suitable flumes are constructed under the floor or in the side piers that connect with the bodies of water above and below the dam and with the interior gate chamber. Valves in the operating flume regulate the pressure of water in the chamber. To raise the gate from a depressed position the operating flume is opened to the higher level of water and closed to the lower. The hydrostatic pressure causes the gate to rise. To depress the gate the valves are reversed, closing the operating flume to the higher level while opening it to the lower. By an adjustment of the valves the relative pressure under the leaves can be varied and the gate made to assume and retain a desired position, thus controlling the quantity of discharged water. The practice nowadays is to use a reciprocating valve or valves, which are set by an attendant in one motion. The ease with which one man can control the movement of a long bear-trap is one of its marked features.

The design did not receive from American engineers the support that it was entitled to, perhaps, because the development of our internal waterways on a large scale was not undertaken until after the French made an unfortunate construction of a bear-trap on the River Marne, and forthwith condemned it. The experience in France was widely published and served to prejudice our own engineers. It is surprising that the French should have proportioned a gate contrary to the simplest and plainest laws in hydromechanics, astonishing that we should have accepted their opinion without so much as a protest, and singular that a gate presenting so many possibilities should not have been studied. The problem is a simple one.

The effect of the Marne gate may be observed in the two quotations given below, which express the then current ideas on this style of a dam. Two distinguished American engineers reported, in 1875:—

"The fact that this system [bear-trap] has been in use in France for many years to provide artificial waves for lumbering, and yet has not been adopted on the larger rivers, is sufficient to condemn it."

An eminent English authority describing, in 1882, the Marne bear-trap, writes:—

"In order to work this weir properly by water pressure as originally intended, it would be necessary to provide a reservoir at a suitable level for ensuring the required pressure. . . . . It is improbable, therefore, that this type of weir will ever be erected again."*

* Rivers and Canals, Harcourt, p. 121.

In contrast to these views is that of Ashbel Welch, in the address quoted above. Mr. Welch said:—

"The bear-trap locks [White's on the Lehigh] have given the hint for several devices since used, and are well worthy of an examination.

"It is well worth inquiry whether these bear-trap gates would not be the best possible, and possibly the cheapest, for letting the water rapidly out of a reservoir for scouring purposes. A full stream could be set running in a few seconds, and the flow could be regulated with perfect ease and stopped at any moment. . . .

"In many rivers it is desirable to dam the stream back at low water, and let it run freely at high water. In Belgium, on the Meuse, they use needle dams for this purpose. Another probably better adjustable dam is in use in France. The bear-trap gates, with proper appliances, on a solid platform at the bottom of a river, would enable a man on shore to raise a dam across that river, or if raised, to lower it to the bottom, in a few moments.

"I have used this construction for a fish sluice in a permanent dam, by which the water ran freely through the sluice when necessary and at other times was retained at full height."

Mr. Welch's bold recognition of the bear-trap was the commencement of a revival in the United States of Mr. White's gate.

The next well-known engineers to look with favor upon the bear-trap were a board of United States officers. They recommended (1883–4) its adoption in the Beattyville dam, Kentucky River. The district engineer made the plans and in 1886 built two gates, each 60 feet long in two passes.*

We had not yet reached that point where we were willing to entirely discredit the French conclusions. Their influence was felt in the design by accepting M. De Lagrenee's assertion that "a head of two feet would be required to raise the gate," and it was concluded that the passes could not "always be closed without some auxiliary method of raising a temporary head."

Later American experiments and studies show that a more sensitive gate might have been built; nevertheless, the officer was enabled the following year to report:— "The gate worked perfectly at all stages of the water, and demonstrated the fact that the gates in both passes could be worked perfectly by one culvert in the middle of the wall, and that no further power was necessary, the pool raising the gate as it rose."†

* Drawings shown on sheets 1, 2 and 3, opp. p. 1746, Annual Report, Chief of Engineers, U. S. A., Part 3, 1884.

† Annual Report, Chief of Engineers, U. S. A., 1887, Part 3, page 1873.

The Beattyville passes have since been replaced by a lock for other reasons than the working of a bear-trap.

In 1887, the late Col. Merrill proposed to build a drift pass, 52 feet wide, closed by a bear-trap, in the Davis Island dam, Ohio River. The pass was built in 1888–9, and has since been in constant use.

The experience on the Kentucky River led to a better proportioned design on the Ohio, and for the same reason a still better one would follow in a third construction.

During these years bear-traps were common in the mountains of Pennsylvania, but it does not appear that the builders attempted a mathematical discussion to guide them in their work. If they did, their light was hidden under a bushel, for there is no published evidence of a discussion, nor even a description of the dams.

It was about the time of the building of the drift pass in the Davis Island dam that our engineers recognized the necessity for a better understanding of the distribution of the forces on the gate. The writer recalls that in a preliminary study for a bear-trap, a board of the United States engineers, in October, 1892, directed his attention to this point which he had not fully appreciated, but caused Captain Chittenden and himself to investigate the subject, resulting in the two analyses given later on in this paper.

Mr. White's design of a bear-trap, when in an intermediate position, did not provide an even slope for the discharged water and floating bodies. To remedy the defect, if it may be termed one, Mr. John Du Bois, of Williamsport, Pa., invented, and, in 1862, patented a modification (Plate 2, Fig. 2) which is described in the Patent Office records as "A dam shoot having an apron made in sections *H H′*, hinged together at their junction as at *i*, the lower section *H′* articulating upon a fixed hinge, and the upper end of the section *H*, traveling in a horizontal slot at the bottom of flume."

Mr. Du Bois' gate was soon followed (1870) in France by M. Carro's device, illustrated on Plate 2, Fig. 3.

Neither of the alterations were improvements on the prototype, but they were admissible as variations.

In 1878, one of Mr. Du Bois' gates was designed and built by James McIntyre, a contractor, in the lumber shoot of the Dells Improvement Company's dam on the Chippewa River at Eau Claire, Wis. Its dimensions were: length, 20 feet; width upstream leaf, 16 feet; width downstream leaf, 48 feet; total width when horizontal, 64 feet; rise, 7 feet. The sliding extremity of the upstream leaf was fastened to a timber the two ends of which projected 12 inches; they were rounded and moved in slots cut in the walls of the shoot. The safe passage of rafted cribs of lumber required an easy slope to the lower leaf, hence the ex-

ceptional width of the latter. The Eau Claire gate gave satisfactory service, and we have described it thus fully as it is now of historical interest in having ultimately led to the inventions of Messrs. Parker and Lang.

Two other defects in Mr. White's dam are the friction between the sliding parts and the length of base required, neither of which were improved upon by Mr. Du Bois and M. Carro. These defects were probably perceived by M. Girard, who conceived the first real improvement (Plate 2, Fig. 4). In 1868, he secured a French patent on replacing the straight downstream leaf by a folding one hinged to the floor and to the downstream end of the upper leaf. In depressing the gate, the lower leaf folded inwardly.

The writer has not learned of a reference to this last design in any publication, outside of the Patent Office records, and we assume that it has been unknown to Americans, otherwise we cannot account for the constructive idea contained therein lying dormant until revived nineteen years later, through the independent thought of an ingenious American, Thomas Parker, of Menomonie, Wis. It seems reasonable to conclude that the foreign engineers familiar with M. Girard's patent did not fully grasp its latent merits. The propositions* to apply it and Mr. White's design to lock gates after turning them on edge were to convert good lock gates into poor ones, and showed efforts as misdirected as some American suggestions.

In an attempt to improve on the old bear-trap, Hon. Felix R. Brunot, of Allegheny, Pa., patented, in 1867, a "sluice gate for dams and locks" to consist of a "hollow sluice gate furnished with valves for the admission or exit of water—so as to raise or lower the gate at pleasure." At one time, the adoption on the Ohio River of Mr. Brunot's plan was seriously considered. The engineers first proposed to combine it with a bear-trap by substituting for the solid lower leaf of the latter, Mr. Brunot's pontoon (Plate 2, Fig. 5), but later decided, provisionally, in favor of making the upper leaf a pontoon and omitting the lower one (Plate 2, Fig. 6). Subsequently the entire scheme was wisely abandoned. It was evidently the intention to change the specific gravity of the hollow leaf by alternately introducing and withdrawing water. The proposition was defective as all attempts of that kind are apt to be. The acceptable gate should respond quickly and surely to the effect alone of the available fall in the stream.

January 11, 1881, a patent was issued to Mr. Du Bois for an apron leaf attached to the free end of the upstream leaf of the common bear trap, the other end sliding on the floor below the gate (Plate 2, Fig. 7).

Engineering News, March 21, 1895.

The purpose sought was the same as in his patent taken out in 1862—to provide an even slope for the discharged water and floating bodies. Incidentally the apron will perform a service that may become as important as the one for which it was intended, by preventing a deposit of sediment upon the downstream leaf.

About this time, or maybe earlier, objection was urged against long bear-trap gates in consequence of their liability to warp and twist when in motion. The tendency has perhaps been overestimated and the evil effect exaggerated. The warping may have been more unsightly than hurtful. Be that as it may, the criticism was ever recurring and to prevent the twist, Mr. Du Bois proposed, in 1883, to attach a set of racks to the under side of the lower leaf and another set to the downstream end of the apron. Each set of racks engaged in a corresponding set of pinions keyed to a shaft. It was hoped that the weir could be forced to move with an even crest. More recent trials indicate that the remedy lies not in additional mechanism, but in careful construction

Besides the modifications described, many others of little or no value were patented.*

No positive advancement was made over Mr. White's pattern until 1887, when Thomas Parker received a patent for the improvement that marks an era in the development of bear-trap gates.

Before proceeding with the description of Mr. Parker's invention we will briefly state the two chief defects in the old form:

(1) Friction between the two leaves.

(2) Inability to construct a high dam upon a short base.

Friction means more head. A long base means greater cost.

Mr. Parker sought to minimize these defects. His gate (Plate 2, Fig. 8) consists essentially of three leaves hinged to each other and to the floor. The two upstream leaves fold inwardly and underneath the downstream leaf. It is M. Girard's gate turned end for end. Mr. Parker provided an upstream apron, or idler, as he called it, attached at one end loosely to the crest of the weir, the other end sliding upon the floor above the gate or upon the folding leaf. The idler, as its name implies, is no essential part of the design; the purpose is to protect the folding joint against a lodgment of chips and the like, and to provide a sheer for floating debris, roots and trees. In some situations the idler is unnecessary, but when it is used, grated apertures must be provided to admit a free circulation of water on both sides of idler.

It will be noted that we have not attributed to the French gate an influence upon the evolution of the modern bear-trap. It was to all intents and purposes, an unknown invention.

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*Wood, in 1871, Werner, in 1873, and Smith, in 1875.

In 1890, appeared the device (Plate 2, Fig. 9) of Robert A. Lang, of Eau Claire, Wis., in which he substituted chains or rods for the upper one of Parker's folding leaves and converted the idler into a functional part of the weir, but in doing so, he reintroduced the objectionable feature of friction. For this reason some authorities deprecate the dam. Captain Chittenden, in an excellent article that appeared in the *Engineering News*, February 7, 1895, says:

"The reintroduction of sliding friction is a distinct step backward, and this is at once apparent in the results obtained from mathematical analysis. Although this analysis has not yet proceeded far enough to make possible the presentation of a full set of curves it clearly indicates that the Lang gate is inferior to the Parker in efficiency."

Other engineers contend that in the position of the gate where the friction effect is most damaging, it is overcome by the weight of that portion of the gate suspended in air; a series of practical trials will decide the question. That the friction is a factor to be considered, was evidenced in the gate built on the St. Croix River at Nevers, Wis., where it was found that the gate would not pass the critical position until after rollers were put on the free end of the idler.

The modifications of the Parker gate that were patented by R. A. Lang, might readily suggest themselves for trial to experts examining into the merits of the various designs. Major Marshall and his assistants perceived the idea and studied it before Lang published his or took out letters patent.

The reversal of the Parker gate is another instance of many minds reaching the same end. Horace Harding, United States Assistant Engineer in the Mobile district, planned a reversed Parker, minus the idler, for a lock gate in 1892; since then several have independently proposed the same change.

The following is a list of the improved bear-trap gates that have been built:

PARKER GATES.

1888. Menomonie River, Menomonie, Wis., for the Knapp Stout & Co. Company. Length, 14 feet; height, 7 feet.

1890. Milwaukee River, for the City of Milwaukee, Wis., two. Length of each, 23 feet; height, 14 feet.

1892. Muscle Shoals Canal, Tennessee, for United States Government. Length, 40 feet; height, 8.5 feet.

LANG GATES.

1889–90. St. Croix River, at Nevers, Wis., for the St. Croix Lumbermen's Dam and Boom Co., of Stillwater, Minn.:

1—Length,	80 feet;	height,	14 feet.		
1	"	24 "	"	14 "	
1	"	20 "	"	14 "	

1891–2. Mississippi River at Little Falls, Minn., for Little Falls Water Power Co. Length, 60 feet; height, 7 feet.

1892–3. Chippewa River, at Little Falls, Wis., for Chippewa River Improvement and Log Driving Co. Length, 58 feet; height, 12 feet.

1894–5. Chippewa River, at Chippewa Falls, Wis., for Chippewa Lumber and Boom Co. Length, 80 feet; height, 6 feet.

1895. Sandy Lake Reservoir, Minn., for United States Government:
1—Length, 11 feet; height, 12 feet.
2—Length of each, 40 feet; height, 13 feet.

The two latter are both sluice and lock gates.

The untimely death of Mr. Parker interrupted the erection of his gates.

With the exception of the Sandy Lake gates, and possibly the one at the Muscle Shoals Canal, all of the above were built on low weirs and hence cannot be said to give thorough tests of their value as movable dams that must lower even with the bed of the stream. The Sandy Lake gates cannot be tried for all conditions of head until late in the spring of 1896.

Backwater, as will be explained in the analysis, has a material effect upon the operation of the improved forms, and therefore a gate erected on a weir, even if it is a low one—a raised foundation for instance,* is not worked under the conditions that obtain in a river where there is navigation in both directions.

The studies of well-known engineers during the past few years have awakened a lively interest in bear-trap gates. It is highly probable that the continued efforts will evolve a design better than those now known.

In detailing the history of the bear-trap, we have not mentioned the one proposed for the regulating works on the Chicago Drainage Canal. We do not know the plan except in a general way, and as we may be misinformed upon its details, we abstain from discussing it. We are of the opinion, however, that the engineers could have obtained a better gate in one of three standard designs—the old bear-trap, the Parker, or the Lang.

ANALYSES OF THE BEAR-TRAP GATES.

The following analyses are the joint production of Captain H. M. Chittenden and the writer. They were undertaken in 1892 in order to replace with a rational formula the rule passing current among engineers for proportioning an old bear-trap. The interest incited encouraged us to treat the Parker gate in a similar manner, which we did in 1894.

* The crests of the Nevers gates when lowered are 7 feet above low water; the Milwaukee gates are 0.75 feet; the Menomonie, St. Croix, Chippewa and Mississippi river gates are perhaps intermediate between the first two.

At the outset the problem was confronted, of determining the profile of the water surface passing over the old bear-trap when fully depressed. A little thought showed the futility of such an attempt, and further that it would unnecessarily complicate the analysis. The expedient was hit upon, of supposing a stop-plank to be erected at the crest of the gate, or lower end of leaf X, and the water surfaces above and below level, but with a difference in elevation equal to that of the water surfaces at the inlet and exit of the operating flume. The supposition does not lead to a correct solution, but the error is on the side of safety, and so simplifies the process as to make the analysis possible and a mere question of elementary algebra. To this expedient is ascribed our success, and because of its omission by our predecessors, their failure to arrive at as good a result.

It is also assumed that the leaves are lines without thickness or weight.

With these preliminary remarks, we proceed to the

ANALYSIS OF THE OLD BEAR-TRAP.

There are two critical positions for the gate, *i. e.*, two positions where the force (head) required to produce movement must be a maximum. They are the two extremes—gate depressed and gate elevated. Therefore it is not necessary to extend the investigation beyond the two cases.

Gate Depressed.—In Plate 3, Fig. 1, X is the upstream leaf; Y the downstream, Z the lap of the upstream over the downstream leaf; Q the distance between the hinges; h'' the head caused by a stop-plank; P_1 the downward pressure; P_2 the upward pressure, and w the weight of a cubic foot of water.

$$P_1 = \frac{X \,.\, Z - \frac{1}{2} Z^2.}{X - Z} h'' \,.\, w \tag{1}$$

$$P_2 = \tfrac{1}{2}\, Y \,.\, h'' \,.\, w \tag{2}$$

and when $P_1 = P_2$,

$$Y = \frac{2 \,.\, X \,.\, Z - Z^2}{X - Z} \tag{3}$$

Equation (3) gives the relation between X, Y and Z, when $P_1 = P_2$. In practice, it is necessary that the upward pressure shall be in excess, in order to put the gate in motion and overcome friction.

Let $n \cdot P_2 = P_1$. n being a proper fraction, then

$$Y = \frac{2 \,.\, X Z - Z^2}{n\,(X - Z)} \tag{4}$$

and

$$Z = \tfrac{1}{2}\,(2 \cdot X + n \cdot Y) \pm \sqrt{\tfrac{1}{4}\,(2 \cdot X + n \cdot Y)^2 - n\,X \cdot Y} \qquad (5)$$

From Plate 3, Fig. 1:

$$Q = Y + X - Z = Y\,(1 - \tfrac{1}{2}\,n) \pm \sqrt{\tfrac{1}{4}\,(2 \cdot X + n\,Y)^2 - n \cdot X \cdot Y} \qquad (6)$$

As the value of Q does not affect the relative values of X, Y and Z, we may, for convenience, place it equal to unity; then solving equation (6) for Y and X, we have

$$Y = \frac{1 - \frac{1}{2}\,n}{1 - n} - \sqrt{\frac{X^2}{1 - n} + \frac{1}{4}\left(\frac{n}{1 - n}\right)^2} \qquad (7)$$

$$X = \sqrt{(1 - n)\;Y^2 - 2\,(1 - \tfrac{1}{2}\,n)\;Y + 1} \qquad (8)$$

For $n = 1$, *i. e.*, when upward pressure equals downward pressure,

$$Y = 1 - X^2 \qquad (9)$$

" $n = \frac{8}{10}$, *i. e.*, when upward pressure equals $1\frac{1}{4}$ times downward pressure, $Y = 3 - \sqrt{5\,X^2 + 4}$ (10)

" $n = \frac{3}{4}$, *i. e.*, when upward pressure equals $1\frac{1}{3}$ times downward pressure, $Y = 2\frac{1}{2} - \sqrt{4\,X^2 + 2\frac{1}{4}}$ (11)

" $n = \frac{2}{3}$, *i. e.*, when upward pressure equals $1\frac{1}{2}$ times downward pressure, $Y = 2 - \sqrt{3\,X^2 + 1}$ (12)

" $n = \frac{1}{2}$, *i. e.*, when upward pressure equals 2 times downward pressure, $Y = 1\frac{1}{2} - \sqrt{2\,X^2 + \frac{1}{4}}$ (13)

By supplying in equations (9) to (13) inclusive, the values of X between 0 and 1, we ascertain the corresponding values of Y; the base or distance between hinges being unity. In this manner, we drew the curves, Plate 4, showing the apexes of an infinite number of old bear-trap gates when up full height.

An inspection of the curves will show that they are quite flat near the top, and the proportion of the leaves has quite a range, even to having Y less than X, without seriously decreasing the height. In fact, in some cases, it might be preferable to sacrifice height in order to decrease the width of Y and lessen the total strain upon that leaf.

The widths of the leaves for a maximum height can be scaled from Plate 4, or can be found mathematically as follows:

Let H represent the height or perpendicular distance from the apex of gate to base; β the angle opposite leaf X.

$$\text{Cos}\,.\,\beta = \frac{Y^2 + 1 - X^2}{2 \cdot Y} = \tfrac{1}{2}\,n \cdot Y + (1 - \tfrac{1}{2}\,n) \qquad (14)$$

$$1 - \cos^2 . \beta = \sin^2 . \beta = 1 \tfrac{1}{4} n^2 \cdot Y^2 - n \left(1 - \tfrac{1}{2} n\right) \cdot Y - \left(1 - \tfrac{1}{2} n\right)^2 \qquad (15)$$

$$H^2 = Y^2 \sin^2 . \beta = Y^2 - \tfrac{1}{4} n^2 \cdot Y^4 - n \left(1 - \tfrac{1}{2} n\right) Y^3 - \left(1 - \tfrac{1}{2} n\right) Y^2 \qquad (16)$$

Place the first differential coefficient of equation (16) equal to O then when H is a maximum

$$Y = {}^1/n \cdot \sqrt{\tfrac{1}{4} \left(1 - \tfrac{1}{2} n\right)^2 + 2} - \tfrac{3}{2} \left(\frac{1 - \tfrac{1}{2} n}{n}\right) \qquad (17)$$

From equations (8), (16) and (17) we have, when H is a maximum and

for $n = 1$, $Y = .6861$; $X = .5602$; $H = .369$
" $n = \frac{8}{10}$, $Y = .6821$; $X = .5239$; $H = .333$
" $n = \frac{3}{4}$, $Y = .6811$; $X = .5144$; $H = .323$
" $n = \frac{2}{3}$, $Y = .6794$; $X = .4979$; $H = .320$
" $n = \frac{1}{2}$, $Y = .6762$; $X = .4629$; $H = .266$

Gate Elevated.—The second case we have to consider is; when the gate is raised can it be lowered?

If the interior angle between the leaves becomes 90° or less, the gate will remain up; it is important that the angle should not be less than 105° or 100°.

The curves (Plate 4) show that in no reasonable instance when $n = 1$ or $n < 1$ will the limit be reached.

The value of n in the Marne gate is 1.32; in the Beattyville gate, 1.17; and in the Davis Island gate, 0.82. There is a good reason why the French gate was defective, and if reliance can be placed upon the drawings given on Plate 35, third volume "Cours de Navigation Interieure," by H. De Lagrenée, the ill proportions were aggravated by a sill supporting the free ends of the lower leaf, which obstructed the circulation of water underneath the gate.

By our reasoning the Beattyville gate would not rise. It did rise because the side piers and the operating flume extended 105 feet above the crest. There was so much fall in the distance that the effect was to put a greater pressure under the leaves than was applied to the top side of the upstream leaf. This sort of construction, and it is a good one, when circumstances will permit, is frequently taken advantage of to insure the working of the weir.

The skeletons of the three gates show in their relation to the curves, Plate 4, that the proportions might have been improved.

The old bear-trap has been a useful and much abused gate of unique design and great possibilities, but in view of the superiority of the im-

proved forms it is unlikely that Mr. White's original design will again be resorted to, except in remote and inaccessible localities where skilled labor and metal work are difficult to obtain, and where extreme simplicity is a desideratum.

In designing one of these movable weirs, we suggest that the factor "n" should not exceed $\frac{8}{10}$ or better still $\frac{2}{3}$. The difference in height between the two is insignificant, while the resultant initial upward pressure is largely increased by the smaller value of the factor. The addition of Du Bois' apron will materially improve the working of the gate.

ANALYSIS OF THE PARKER GATE.

The process for the analysis of the Parker gate direct and reversed is the same. The analytical difference between the two forms is in the opposite direction of the forces; plus in one case becomes minus in the other. The difficulty to be overcome in a direct gate by a correct proportioning of the leaves is the final downward movement and in a reversed gate the initial upward movement.

We will suppose that the upper level of water follows the crest of the weir and that the two continue coincident.

It is observed that the ratio of the lowering to the lifting forces is least when the crest of the gate is just disappearing beneath the water; or if there is no backwater, when the gate is assuming a horizontal position. Hence, if the relative widths of the leaves are proportioned for these positions, the gate will operate in all others. See Plate 3, Fig. 2.

$\overline{D\,G}$ = base = 1 and all other lineal measurements, fractional parts of the base. Let the nomenclature be as in the figure.

From the conditions of the problem:

$$X + Y - Z = 1 \tag{18}$$

$$Y^2 + Z^2 = 1 - 2\,X + X^2 + 2\,Y Z \tag{19}$$

By geometry,

$$\text{Cos}\,.\,\varphi = \frac{X^2 + 1 - (Y + Z)^2}{2\,X} \tag{20}$$

Combine equations (18) and (20), and solve for Z:

$$Z = \tfrac{1}{2} \cdot \left(\sqrt{1 + X^2 - 2\,X \cos.\varphi} - (1 - X)\right) \tag{21}$$

From equations (18) and (21):

$$Y = \tfrac{1}{2} \cdot \left(\sqrt{1 + X^2 - 2\,X \cos.\varphi} + (1 - X)\right) \tag{22}$$

Multiply equations (21) and (22):

$$Y \cdot Z = \tfrac{1}{2}\,X\,(1 - \cos.\,\varphi). \tag{23}$$

By geometry:

$$g^2 = X^2 + 1 - 2\, X \cdot \cos .\, \alpha \tag{24}$$

$$\text{Cos} .\, \theta = \frac{(Z^2 + Y^2) - g^2}{2 \cdot Z \cdot Y} \tag{25}$$

Combine equations (25), (24), (23) and (19) and solve for sin . α:

$$\sin^2 .\, \alpha = 1 - [1 - \tfrac{1}{2}\,(1 \cos .\, \varphi)\,(1 \cos .\, \theta)]^2 \tag{26}$$

Let P_1, P_2, P_3 and P_4 (Plate 3, Fig. 3) represent the forces due to the hydrostatic pressures on leaves Y and Z.

P_1 may be omitted, as it has no effect on the moment of the gate. Resolve P_3 and P_4 into two forces, P_5 and P_6, acting in the direction of Y and Z respectively. Drop P_6, as it causes only a tensile strain in leaf Y, then:

$$P_5 = \frac{P_4}{\sin \theta} - P_3 \cot. \theta \tag{27}$$

The forces that produce motion in the gate are P_2 and P_5.

With the center of moments around G, the equation for equilibrium is—

$$P_2 \cdot \cos .\, Y - P_5 \sin Y = 0 \tag{28}$$

substitute for P_5 its value in equation (27) and equation (28) reduces to

$$P_4 - P_3 \cdot \cos .\, \theta - P_2 \cdot \cot .\, Y \cdot \sin .\, \theta = 0. \tag{29}$$

Equation (29) is the general equation of the problem. It must be satisfied for all positions of the gate higher than that of the crest at surface of water in lower pool. If, therefore, we apply it to the critical position, *i. e.*, that position where the ratio of lowering to lifting force is least, there will be a preponderance of lowering force to depress the gate from any higher position. The equation may be treated separately for two conditions, viz.:

1. When there is no backwater, as in the case of a weir at the crest of a fall, natural or artificial.

2. When there is backwater.

1. When there is no backwater. Referring to Plate 3, Fig. 3, $M = O$, $X = Z$, and the forces are

$$P_2 = \tfrac{1}{6}\, h''' \cdot Z \tag{30}$$

$$P_3 = \tfrac{1}{3}\, h''' \cdot Z \tag{31}$$

$$P_4 = \tfrac{1}{2}\, h''' \cdot Y + \tfrac{1}{6}\, h' \cdot Y \tag{32}$$

Substitute in equation (29) the above values of P_2, P_3 and P_4,

$$\left(\frac{h'}{h'''} + 1\right) Y + 2\,(Y - Z \cdot \cos \theta) - Z \cdot \sin \theta \cdot \cot .\, Y = 0. \tag{33}$$

When the gate is assuming a horizontal position, $\frac{h'}{h'''} + 1 = \frac{0}{0} + 1$ and $\sin \theta \cdot \cot V = 0 \cdot \infty$.

After being evaluated,* the two indeterminate expressions reduce to

$$\frac{h'}{h'''} + 1 = \frac{1 - X}{\sqrt{\tfrac{1}{2}(1 - \cos \varphi)} - Z} \qquad (40)$$

and

$$\sin \theta \cdot \cot V = \frac{1 - X}{Y - \sqrt{\tfrac{1}{2}(1 - \cos \varphi)}} \qquad (43)$$

With the aid of equations (18), (40) and (43), and $\cos \theta = 1$, equation (33) can be reduced to

$$(1 - \cos . \varphi) - \sqrt{\tfrac{1}{2}(1 - \cos . \varphi)} \cdot (Y + Z) - (1 - X)^2 = 0 \qquad (44)$$

For $Y + Z$, substitute its value as found by adding together equations (21) and (22), and reduce equation (44) to

$$(1 - X)^3 - 2\sqrt{\tfrac{1}{2}(1 - \cos \varphi)} \cdot (1 - X) + (1 - \cos . \varphi)^2 = 0 \qquad (45)$$

Equation (45) can be solved for X by trials. Angle φ is fixed by

* To evaluate $\frac{h'}{h'''} = \frac{0}{0}$, proceed thus (Plate 3, Fig. 4):

$$\sin \beta = \sin (A - B) = \frac{1}{g^2} [X \sin \alpha (Y - Z \cdot \sin \theta) - Z \cdot \sin \theta (1 - X \cos \alpha)] \qquad (34)$$

$$\cos \beta = \cos (A - B) = \frac{1}{g^2} [(1 - X \cos \alpha)(Y - Z \cos \theta) + X \sin \alpha \cdot Z \cdot \sin \theta] \qquad (35)$$

$$\frac{h'}{h'''} = \frac{Y \cdot \sin \beta}{Z \cdot \sin (\theta - \beta)} = \frac{X \cdot Y \cdot \frac{\sin \alpha}{\sin \theta} - Y \cdot Z}{Y \cdot Z - X \cdot Z \frac{\sin \alpha}{\sin \theta}} \quad \text{for } \alpha = 0 \text{ and } \theta = 0 \qquad (36)$$

To evaluate $\frac{\sin \alpha}{\sin \theta} = \frac{0}{0}$ (equation 36), square the expression and from equation (26) we have

$$\frac{\sin^2 \alpha}{\sin^2 \theta} = \frac{1 - [1 - \tfrac{1}{2}(1 - \cos \varphi)(1 - \cos \theta)]^2}{\sin^2 \theta} \qquad (37)$$

The first differential coefficient of numerator and denominator of right-hand member of equation (37) is

$$\frac{-2\{1 - \tfrac{1}{2}(1 - \cos \varphi)(1 - \cos \theta)[-\tfrac{1}{2}(1 - \cos \varphi)] \sin \theta\}}{2 \cdot \sin \theta \cdot \cos \theta}$$

Cancel $\sin \theta$, then when $\theta = 0$, above expression becomes $\frac{1}{2}(1 - \cos \varphi)$, or

$$\left.\frac{\sin \alpha}{\sin \theta}\right]_{0,0} = \tfrac{1}{2}(1 - \cos \varphi) \qquad (38)$$

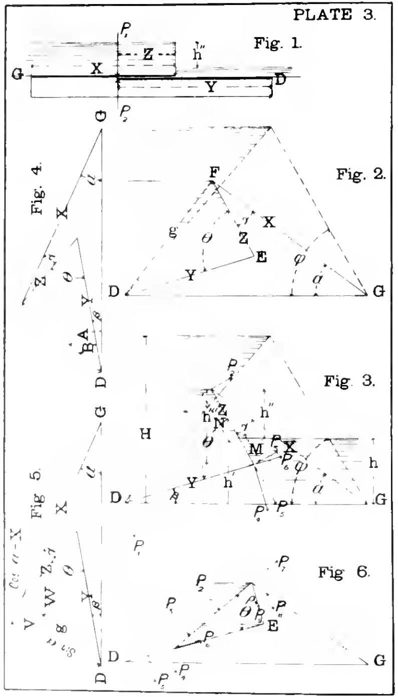


PLATE 3.
Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
Fig. 6.

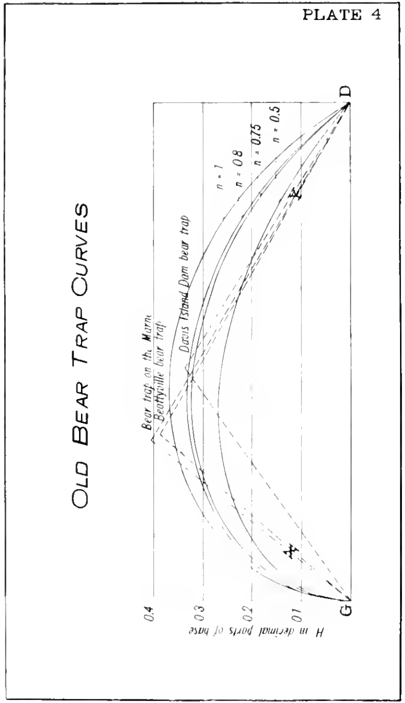


PLATE 4
OLD BEAR TRAP CURVES
n = 1
n = 0.8
n = 0.75
n = 0.5
Davis Island Dam bear trap
Beattyville bear trap
Bear trap on the Marne
H in decimal parts of base

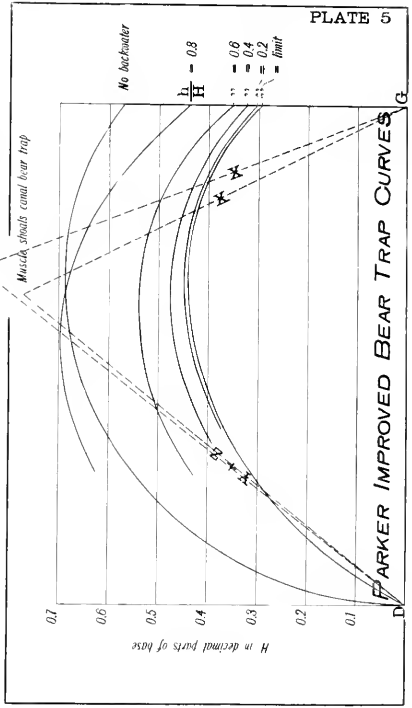


PLATE 5
PARKER IMPROVED BEAR TRAP CURVES
No backwater
h/H = 0.8
" = 0.6
" = 0.4
" = 0.2
" = limit
Milwaukee River Dam bear trap
Muscle shoals canal bear trap
H in decimal parts of base

the slope leaf X shall take when gate is raised full height. Y and Z can be obtained from equation (21) or (22), and (18).

For the condition of absolutely no backwater, *i. e.*, when the backwater does not reach to the base of the gate, equations (45), (21) or (22), and (18) give the proportions for a gate that will lower for any height of water in the upper pool.

2. When there is backwater.

Inasmuch as the most difficult position, with backwater as a condition, for the gate to pass in its downward motion, is when the crest approaches to a level with the surface of water in the lower pool, we may take the expression for the forces from a position of the gate where the hinge E is submerged, then

$$P_2 = \tfrac{1}{2} h'' \cdot M + \tfrac{1}{6} h'' \cdot \frac{X^2}{Z} \tag{46}$$

$$P_3 = \tfrac{1}{2} h'' \cdot Z - \tfrac{1}{6} h'' \cdot \frac{X^2}{Z} \tag{47}$$

$$P_4 = \tfrac{1}{2} h'' \cdot Y. \tag{48}$$

Substitute in equation (29) the above values of P_2, P_3 and P_4,

$$\tfrac{1}{2} h'' Y - \left(\tfrac{1}{2} h'' Z - \tfrac{1}{6} h'' \frac{X^2}{Z} \right) \cos. \ \theta - \tfrac{1}{2} h'' \cdot M + \tfrac{1}{6} h'' \frac{X^2}{Z} \cdot \sin \theta \cdot \cot. \ \Upsilon = 0 \tag{49}$$

Introduce equation (38) in equation (36), we have

$$\left.\frac{h'}{h'''}\right]_{0,0} + 1 = \frac{(Y - Z)\, X \cdot \sqrt{\tfrac{1}{2}(1 - \cos \varphi)}}{Y \cdot Z - X \cdot Z \cdot \sqrt{\tfrac{1}{2}(1 - \cos \varphi)}} \tag{39}$$

Substitute in above, equations (18) and (23), and reduce

$$\left.\frac{h'}{h'''}\right]_{0,0} + 1 = \frac{1 - X}{\sqrt{\tfrac{1}{2}(1 - \cos \varphi)} - Z} \tag{40}$$

To evaluate $\sin \theta \cdot \cot \Upsilon = 0 \cdot \infty$, proceed thus (Plate 3, Fig 5)

$$\sin \theta \cdot \cot \Upsilon = \sin \theta \, \frac{\cos \Upsilon}{\sin \Upsilon}$$

$$= \sin \theta \, \frac{\cos (V + W)}{\sin (V + W)}$$

$$= \frac{Y \cdot \sin \alpha \,.\, \sin^2 \theta - (\cos \alpha - X)(Z - Y \cos \theta) \sin \theta}{(\cos \alpha - X)\, Y + (Z - Y \cos \theta) \dfrac{\sin \alpha}{\sin \theta}} \tag{41}$$

For $\alpha = 0$ and $\theta = 0$, equation (41) reduces to

$$\sin \theta]_0 \cdot \cot \Upsilon]_0 = \frac{1 - X}{Y - \dfrac{\sin \alpha}{\sin \theta}} \tag{42}$$

Substitute for $\dfrac{\sin \alpha}{\sin \theta}$ its value, as given in equation (38), then equation (42) becomes

$$\sin \theta]_0 \cdot \cot \Upsilon]_0 = \frac{1 - X}{Y - \sqrt{\tfrac{1}{2}(1 - \cos \varphi)}} \tag{43}$$

When the gate is just disappearing beneath the backwater, $M = Z$, $N = O$, and $h'' = O$.

Equation (49) now reduces to

$$Y - Z \cdot \cos. \theta - Z \cdot \sin. \theta \cdot \cot. Y = O. \tag{50}$$

In place of $\sin. \theta \cdot \cot. Y$ insert its value as given in equation (41) and also make the following substitutions:

From equation (1),

$$Y = 1 - X + Z \therefore Y - Z \cdot \cos. \theta = (1 - X) + Z(1 - \cos. \theta)$$

From equation (1),

$$Z = -(1 - X) + Y \therefore Z - Y \cos. \theta = -[(1 - X) - Y \cdot (1 - \cos. \theta)]$$

From equation (1), $Y - Z = 1 - X$.

From equation (23), $Y \cdot Z = \frac{1}{2} X (1 - \cos. \varphi)$,

From equations (25), (24), (23) and (19),

$$(1 - \cos. \theta)(1 - \cos. \varphi) = 2(1 - \cos. \alpha). \tag{51}$$

From trigonometry,

$$\sin. \theta \cdot \cos. \alpha - \sin. \alpha \cdot \cos. \theta = \sin. (\theta - \alpha)$$

then equation (50) will reduce to

$$(1 - X) \frac{2 \sin. (\theta - \alpha) - X \cdot \sin. \theta}{2(1 - \cos. \alpha)} - X^2 \sin. \theta + X \sin. (\theta - \alpha) = O. \tag{52}$$

$$\text{and } X = \frac{\sin. (\theta - \alpha)}{\sin. \theta} \tag{53}$$

Angle α is known from the equation:

$$\sin \alpha = \frac{h}{H} \sin \varphi$$

and angle θ is known from equation (51):

$$\cos \theta = 1 - \frac{2(1 - \cos . \alpha)}{(1 - \cos . \varphi} \tag{54}$$

Equation (53) gives value of X for any desired angle of φ. Y and Z can be obtained from equations (21) or (22), and (18). Equation (53) is solved by trials, after first fixing upon the values of φ and $\frac{h}{H}$.

For the condition of backwater there is a limiting case, *i. e.*, when the backwater is infinitesimal, and when the crest of the gate is at the same elevation. $\alpha = 0$ and $\theta = 0$.

To derive the value of X for the limiting case, resume equation (53):

$$X = \frac{\sin . (\theta - \alpha)}{\sin . \theta} \tag{53}$$

$$X = \cos . \alpha - \frac{\sin \alpha}{\sin \theta} . \cos . \theta. \tag{55}$$

For $\alpha = 0$ and $\theta = 0$, equation (55) reduces to

$$X = 1 - \left.\frac{\sin . \alpha}{\sin . \theta}\right]_{0,0} \tag{56}$$

Introduce equation (38) into equation (56), then the latter becomes

$$X = 1 - \sqrt{\tfrac{1}{2}(1 - \cos . \varphi)}$$

SUMMARY OF EQUATION FOR FINDING WIDTHS OF X, Y AND Z.

Depending upon the height of backwater, X is found from one of the three following equations:

1. When there is no backwater,

$$(1 - X)^3 - 2\tfrac{1}{2}(1 - \cos . \varphi)(1 - X) + (1 - \cos . \varphi)^2 = 0 \tag{45}$$

2. When there is backwater.

(*a*) When the height of backwater has a finite value:

$$\begin{cases} X = \dfrac{\sin . (\theta - \alpha)}{\sin \theta} & (53) \\ \sin . \alpha = \dfrac{h}{H} . \sin . \varphi & \\ \cos . \theta = 1 - \dfrac{2(1 - \cos . \alpha)}{(1 - \cos . \varphi)} & (54) \end{cases}$$

(*b*) When the height of backwater is infinitesimal,

$$X = 1 - \sqrt{\tfrac{1}{2}(1 - \cos . \varphi)} \tag{57}$$

Y and Z are found from either of the two following sets of equations, X being known,

$$\begin{cases} Y = \tfrac{1}{2}\left(\sqrt{1 + X^2 - 2X \cos . \varphi} + (1 - X)\right) & (22) \\ Z = X + Y - 1 & (18) \end{cases}$$

$$\begin{cases} Z = \tfrac{1}{2}\left(\sqrt{1 + X^2 - 2X \cos . \varphi} - (1 - X)\right) & (21) \\ Y = 1 + Z - X & (18) \end{cases}$$

From the above formulæ we have prepared the following:

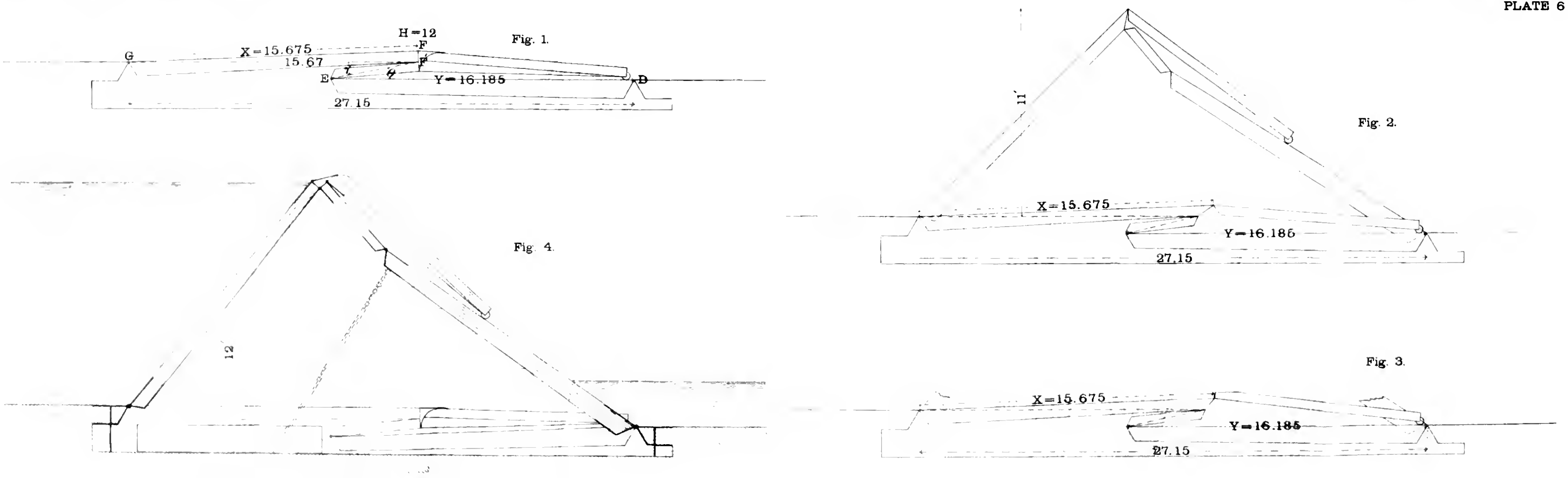
TABLE OF PARKER GATE PROPORTIONS.

φ	No backwater.				$\frac{h}{H} = 0.8$				$\frac{h}{H} = 0.6$			
	X	Y	Z	H	X	Y	Z	H	X	Y	Z	H
10°	.994	.090	.084	.173								
20°	.975	.185	.160	.333								
30°	.946	.280	.226	.473					.855	.322	.177	.427
40°	.905	.376	.281	.582	.968	.353	.321	.622	.784	.430	.214	.504
50°	.854	.470	.324	.654	.896	.456	.352	.686	.702	.533	.235	.537
60°	.793	.560	.353	.687	.800	.558	.358	.693	615	.630	.245	.533
70°	.724	.645	.369	.680	.677	.660	.337	.636	.524	.716	.240	.492
80°	.649	.722	.371	.639	.542	.754	.296	.534	.432	.793	.225	.425
90°	.568	.791	.359	.568	.437	.827	.264	.437	.350	.854	.204	.350

φ	$\frac{h}{H} = 0.4$				$\frac{h}{H} = 0.2$				$\frac{h}{H} =$ limit.			
	X	Y	Z	H	X	Y	Z	H	X	Y	Z	H
10°									.9129	.137	.050	.159
20°									.8264	.267	.093	.283
30°	.782	.362	.144	.391	.748	.383	.131	.374	.7412	.388	.128	.370
40°	.704	.471	.175	.453	.666	.492	.158	.428	.6580	.497	.155	.423
50°	.622	.572	.194	.476	.587	.590	.177	.450	.5773	.59	.173	.442
60°	.538	.664	.202	.466	.509	.678	.187	.441	.5000	.683	.183	.433
70°	.458	.744	.202	.430	.433	.755	.188	.407	.4264	.758	.185	.400
80°	.386	.810	.196	.380	.362	.820	.182	.357	.3572	.822	.179	.352
90°	.322	.864	.186	.322	.302	.871	.173	.302	.2929	.874	.167	.293

We have platted on Plate 5, the curves formed by the apexes of an infinite number of Parker gates for the six conditions of "no backwater" and for $\frac{h}{H} = 0.8, 0.6, 0.4, 0.2$, and limit. On the same base are shown, in outline, the gates built in the Milwaukee River and Muscle Shoals Canal. The relation of the two skeletons to the curves indicates that the gates are not correctly proportioned, being too high for their base. The theory is substantiated by the fact that in both instances the gate cannot be completely lowered by the hydrostatic pressures alone. On the crests of each of the 23 feet long Milwaukee gates, the builder placed 7,500 pounds of iron. The added weight called for a larger initial raising force, which was fortunately available. The head was obtained, as in the case of the Beattyville dam, in the fall from inlet of operating flume to gate. Both incidents prove how "circumstances alter cases," and the opportunity an engineer has to exercise judgment.

PLATE 6



PARKER'S IMPROVED BEAR TRAP GATE REVERSED

Proportioned for all heights of backwater

—

φ

10
20
30
40
50
60
70
80
90

φ

10
20
30
40
50
60
70
80
90

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In the foregoing analysis we did not introduce a factor corresponding to n in the old bear-trap, because in practice it is not convenient to build the gate in a manner that will reduce γ and θ to zero, as would be necessary in order to equilibriate the forces in a depressed gate. In the analysis, $n = 1$; but in actual construction $n < 1$.

Our discussion for the condition of backwater has been criticised by an engineer who contends that the limiting equation alone is applicable. We assumed in the case where $\frac{h}{H}$ has a finite value, that after the crest of the gate is submerged the weight of the released water on leaf X is sufficient to bring it to a horizontal position. We believe we are justified in the assumption because a slope in the water surface between the ends of the operating flume is a prerequisite for the erection of a bear-trap, and because the slope from the crest of the gate to the lower end of the flume can be utilized in depressing the gate.

In this treatment of the Parker gate, we have referred throughout to one built with the folding leaf upstream. The remarks are equally applicable to a gate in a reversed position except that the terms would have been given an opposite meaning.

On Plate 6, Fig. 4, we have drawn a reversed Parker proportioned by the formula for any height of backwater $\left(\frac{h}{H} = \text{limit}\right)$, and $H = 12$ feet. The procedure we follow in laying out a Parker reversed is to place horizontally a line equal to X connecting hinges G and F. (Plate 6, Fig. 1.) Draw another horizontal line ED equal to Y; D being placed at a horizontal distance from G equal to the theoretical base $(X + Y - Z)$. The line ED must be sufficiently below $G - F'$ to prevent the Z-leaf and X-leaf from touching each other except at the hinge F'. A precaution can be taken by inserting a few blocks between the two leaves to maintain a divergence between them. The Z-leaf will be a trifle longer than the figure given in formula and table, but the increased length is more than compensated for by the values of γ and θ, which are a minimum in the positions given. After the gate is fully drawn, allow it to sag until the line GF (top of X-leaf) is horizontal. (Plate 6, Fig. 4.) In this position the gate is fully depressed and should be supported by blocks.

We do not particularly admire the manner of connecting the idler, in Figs. 1 and 4, but it permits building the gate with full dimensions and provides a narrow foot-bridge. Two other connections are shown in Figs. 2 and 3, which both destroy a part of the effective range of the gate. The raised crest in Fig. 3 should be avoided.

We have been impressed with the desirability of a smooth and even surface over a depressed gate and the avoidance of projections against which drift may catch, or a depression that will collect sediment

The same care must be exercised in raising a reversed Parker as in an old bear-trap, so as not to allow the strain to be suddenly applied to the chains.

LANG GATE.

It would have been a pleasure to submit in this paper the results of an analysis of the Lang gate, but we have not had the time to accomplish it. Our investigations demonstrated that the formulæ are difficult, if not impossible, of reduction to the simplicity of the Parker formulæ, and that the final result can only be arrived at through a long and tedious series of trials and approximations.

If any members of the society wish an exercise in mathematics, we commend to them the Lang gate problem. The hydrostatic forces P_2, P_3, P_4 and P_5 (Plate 3, Fig. 6) that tend to produce motion, and friction, P_6, can be assembled at the crest in the three forces P_7, P_8 and P_9, and a formula obtained. It is tolerably well settled that the critical position is in the downward movement when angle θ is approximately 90°, and if while the gate is in this position the backwater reaches above hinge E, the combination of the conditions are most unfavorable for the movement of the gate.

If it should be established that the Lang design is theoretically (omitting friction) as good as the Parker, it may be found that the limiting proportions of the former do not materially differ from those of the latter.

In the absence of a true guide, we suggest to engineers building Lang gates in backwater, not to exceed the Parker dimensions for $\frac{h}{H} =$ limit. Without backwater, the restrictions imposed by the idler ($X +$ idler $=$ base) restricts the height to less than the Parker form.

It is unnecessary for us to enter into a more detailed description of the Lang gate, as it will be fully dealt with in papers to be read before the Society by members and resident engineers.

HEAD REQUIRED TO OPERATE BEAR-TRAP GATES.

Considerable speculation has been indulged in as to the minimum head that will insure the successful operation of bear-trap gates.

There is only one working-dam on record about which specific information is given. U. S. Assistant Engineer William Martin, in local charge of the Davis Island Dam, reported:

"There is but 12 inches reduction in the head when the gate is down, and the resistance to the gate rising being largely increased by the velocity of the water passing through the chute, makes the downward force greater than the lifting power. As a matter of fact, when

necessity requires the bear-trap to be lowered under full head for the purpose of passing drift or otherwise, the pool has to be drawn off 6 inches below the normal level before the gate can be raised again."*

But the specific gravity of the leaves, the size of the operating flume, amount of leakage and pressure that can be maintained in the interior chamber, are not stated. There may be causes other than the proportions of the gate that prevents rising under the conditions cited by Mr. Martin. The same engineer has pointed out that the addition of a Du Bois apron would facilitate the movement of the gate.

We will take this opportunity of emphasizing the necessity for a large operating flume. The question should not be: How small can the flume be made? but: How large can the flume be made without entailing too much expense in the construction and too much power to manipulate the valves?

It is unfortunate that none of the improved bear-traps have heretofore been situated where direct observations could be made. The record of an old style gate is not a guide to the requirements of the more sensitive improved forms. Theoretically, the slightest head will produce motion in the gate, but practically, allowance must be made for friction, excess in weight of gate, effect of foreign matter wedging in the space between the leaves and walls of the sluiceway, sediment, faults in construction and the dynamic effect of swiftly passing water, all of which will take power to overcome.

Pending the publication of trustworthy data derived from experience, an engineer may be taking chances in building a bear-trap of a specific gravity approximately equal to 1, without having available a fall of 6 inches between the inlet and outlet of the operating flume.

APPLICATION OF BEAR-TRAP GATES.

Bear-traps are applicable—

First—To sluices and drift passes. Their adaptability to these purposes is too obvious to need reiteration.

Second—To locks. Engineers and inventors long since recognized the utility of automatic gates in lock construction, and have striven to perfect a device that would meet all objections. Bear-traps were early suggested and have been more persistently advanced since the development of the improved forms.

The proposed manner of working bear-trap lock gates was clearly presented in 1884, by a board of U. S. Engineers, in these words:

"The usual type of bear-trap gate operates very well in a chute where there is a difference of level on the two sides of the gate; but

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* Annual Report, Chief of Engineers, U. S. A., 1892, Part 3, page 1982.

when a pair of bear-trap gates is used, as in a lock, each gate must either be raised or lowered in still water. If the gates are made buoyant they will not sink, and if heavier than water they cannot be raised unless power can be brought to bear. It is possible to obviate these difficulties in this way:

"Let the upper gate be made buoyant; it will then remain up and act as a gate in still water. If now the space underneath the gate be connected with the lower pool by a culvert, the pressure of the upper pool will keep the gate down, and thus the gate can be maneuvered under either condition. For the lower gate the conditions must be reversed. It must be made heavier than water, and can only be raised by bringing the head of the upper pool under it by means of culvert in the side walls."

The operation appears feasible, and for the lower gate is effective. The lifting of the upper gate in still water is dependent upon the buoyancy of the leaves, which at best is a limited force of such small power that the gate might not respond quickly and surely. The use of air chambers to increase the buoyancy is a doubtful expedient. The lower gate can readily be made heavy enough to sink with all desired speed.

It is unlikely that bear-traps will displace the common miter-gates in locks of moderate width, but the former are well suited to the lower gates in wide locks. For a long upper lock gate we look towards another design—possibly upon the lines of the Chittenden drum weir—a heavily weighted gate raised to an erect position by the hydrostatic pressure.

When bear-traps are used, the locks may be filled and emptied by discharging and releasing water over the crests of the gates instead of through culverts. The rapidity of the operation will be governed by the velocity of the current in the lock chamber.

Third—To movable dams. We might well add, to movable dams in some situations or in connection with other types.

We imagine that some of the questions which an engineer would consider before adopting a bear-trap, are:

(1) Will a sufficient head of water be available to move the dam? If not, can a fall be gained, as high water recedes, by arranging the dam in sections, the foundations of which form a series of steps? Can a fall be created by a low auxiliary movable dam above a portion of the main dam, or by raising a part of the dam built of needles or wickets?

(2) What is the character of the sediment carried by the river; is it coarse, or fine and penetrating like Missouri river mud?

(3) To what extent is sediment liable to be deposited upon the dam?

*Annual Report, Chief of Engineers, U. S. A., 1885, Part 3, pages 1863–4.

The questions are pertinent and must be satisfactorily answered, or a bear-trap is out of the question.

An important matter in this connection is the length that it is practicable to build a bear-trap. There are now two gates (Lang pattern) in operation, 80 feet long, each, and one (old style) was built on the Monongahela River by Du Bois, 120 feet long. There is no doubt that these lengths can be considerably increased, but the maximum will probably be reached gradually.

CHOICE OF BEAR-TRAP GATES.

For minor structures in remote localities the old bear-trap need not be ignored. In important works, the Parker, Lang, or some future improvement will supersede the prototype.

Generally speaking, we should say that in masonry dams, where the bed of the sluice is elevated above the lower pool, and where the width of foundation must be curtailed, the Parker is the best publicly known form. In wooden constructions, and in all dams where backwater is met, the choice between the Parker and Lang is not so well defined. Each have advantages that will appeal in a different degree to the hydraulic engineer. For lock gates, the Parker has two distinct merits: the efficiency (ratio of height to base), and the tight chambers formed by the three leaves, the base and walls of the lock, admitting the introduction of the full pressure without separating the parts of the gate. The analysis of the Parker has no bearing upon the design for a lock gate. It is possible to build one that in an erected cross-section would be a right-angled triangle, with an efficiency of 1, but a preference may be given to the form of an equilateral triangle with an efficiency of .866.

As between the Parker direct and reversed, there is but a slight difference in their relative value as lock gates. In sluices and movable dams the direct or reversed is better when the larger part of the fall is below or above the gate, respectively.

The reversed Parker presents a clean and smooth surface for the passage of drift, ice and sediment.

CONCLUSION.

In our effort to curtail the length of this paper we have omitted a reference to many minor details, and have not fully discussed some of the major ones.

Our purpose will be subserved, if we succeed in interesting members of the society in the subject and in provoking a general discussion on the merits of the system.

We are not prepared to state that the best form has been realized. Much may be expected from the continued and intelligent efforts of professional workers.

II. Bear-Trap Gate in Davis Island Dam, Ohio River.

By Wm. Martin, U. S. Assistant Engineer.

The subject of improvement of our waterways has in the last few years become one of unusual interest, not only to the engineer, but also to the industrial classes, by whom it is being taken up as a question involving their existence in the race of competition in trade. In the improvement of the Ohio River at Davis Island Chanoine Dam, with which I am more directly connected, the most practicable type of dam for use on this river has been discussed for a number of years, and with a view of determining the question a number of the Chanoine wickets were removed and a section of bear trap 52 feet long and 9.33 feet high was built in the year 1890, as represented on Plate 2, Fig. 1, of Mr. Powell's paper. This dam has fulfilled the object of its builder, viz: the passage of driftwood, which caused a great deal of annoyance in the practical working of the dam, by becoming entangled in the wickets. The bear-trap facilitated the removal of the large drift by the rapidity with which it could be disposed of. This dam was not properly proportioned for working under the maximum head, which occurs when the river is at its lowest stage. Under the greatest head with which the dam has been operated, the gate will not rise, and this necessitates drawing off the pool six inches, before the dam can be put up. We are now hinging a short apron to the upper leaf 7 feet wide—lapping over the lower leaf in a similar manner to the Parker gate reversed, Plate 6, Fig. 4, of Mr. Powell's paper. This, we believe, will relieve the difficulty we have experienced. On rivers like the Ohio, which carry such large quantities of drift, and in which floods occur at times so rapidly that it becomes impracticable to operate movable dams like the Chanoine, on account of the drift clogging the structure, and making it impossible to lower in time, there should be adopted a type of dam that can be maneuvered under all conditions and stages of water. The simplest form of quick-acting dams that have been tested by experience is the old style bear-trap. The bear-trap dam at Davis Island has filling and discharging conduits in each pier, supplying and discharging the water from both ends of the dam. This arrangement prevents the warping of the gates, but I believe that in a dam of great length this action would still occur notwithstanding that the water was supplied and discharged from each end. Some device to cause the gates to rise uniformly has been the need in all the bear-trap dams that have come under my observation. A good example of this twisting action was seen in the dam built by Mr. Du Bois in Dam No. 1, Monongahela River, referred

to in Mr. Powell's paper. This dam was 120 feet long and about 9 feet high, with the filling and discharging culverts in one pier only. The warpage was so great that in raising the dam, the end next the filling culvert came up about 5 feet in advance of the opposite end, and again in lowering, the same side was in advance the same amount, making a variation of 10 feet in the crest. This amount of twisting action would destroy the structure in a very short time. While this action in a small degree would not be injurious in a properly built structure, it is unsightly in appearance, and should not exist if it can be prevented. How can this be prevented? There are several ways in which it can be accomplished.

1st. By building the dam so tight that the leakage will be reduced to a minimum, and the water thus admitted slowly, distributing the pressure uniformly beneath the gate.

2d. A conduit having a series of vertical vents supplying the pressure uniformly, can be built in the foundation beneath the gate.

3d. By the rack-and-pinion plan proposed by Mr. Du Bois. This I believe is a correct principle, but Mr. Du Bois applied it wrongly, and in so unmechanical a manner that it is not surprising that it failed. The device, as Mr. Du Bois applied it, was as follows: Near the upper end of the lower leaf a series of spuds were hinged, having on their lower side a rack which geared into pinions on a shaft located on the foundation near the hinge of the upper leaf. Any movement in the leaves would cause the shaft carrying the pinions to rotate, moving all the spuds simultaneously and being attached to the lower leaf it would consequently be forced to move uniformly. A better plan for using the rack and pinion would be as follows: On the under side of the upper leaf construct racks of the length of the overlap of the leaves. In the upper end of the lower leaf is a shaft of the full length of the dam, which carries pinions, about ten feet apart, meshing into the racks in the upper leaf. These pinions act as rollers to reduce the friction between the leaves. The leaves are united by a sliding link in order to keep the gearing in contact. Experiments made on the rack-and-pinion device with a good-sized model well illustrate the practicability of the plan to prevent warping of the gate, for, however unevenly the pressure is applied, the gate will rise with a uniformly level crest, but on a dam of considerable size a great risk would be taken, as a stoppage in any one pinion would lock the movement of the leaves or cause a breakage. I am firmly of the opinion that the old style bear trap, properly proportioned and built in a substantial manner, reducing the leakage to a minimum, is capable of successful use in spans up to lengths from 200 to 300 feet.

Of the other types of movable dams I believe none would be so

satisfactory as the old style bear trap, on account of its simplicity and few parts, and on rivers like the Ohio, where such large volumes of drift are carried, I believe the Parker, the Lang and the other types referred to would be impracticable.

III. Bear-Trap Gates in the Navigable Pass, Sandy Lake Reservoir Dam, Minnesota.

By Archibald Johnson, U. S. Assistant Engineer, Member of the Civil Engineers' Society of St. Paul.

Sandy Lake Dam is built across Sandy River about one and a quarter miles by river from its confluence with the Mississippi, and about three-fourths of a mile from Sandy Lake.

Its main purpose is to create a reservoir at Sandy Lake, 9.4 feet above extreme low water; but it is intended also to serve a secondary purpose, that of keeping the Mississippi water out of Sandy Lake, should the latter happen to be low when water is liberated from the reservoirs above at any time for the special benefit of navigation.

The river and harbor act of Congress approved July 13, 1892, required the construction of a navigable pass through the dam. As Sandy River, at the dam site, is only about 125 feet wide, it became necessary to use some form of movable dam in place of the ordinary lock gates, so as to retain control of sufficient waterway. By having such, the reservoir, during flood stages in the Mississippi, may sometimes be filled; or, if the flood occurs in the water-shed of Sandy Lake, the surplus may quickly be drawn off. Further, it increases the efficiency of the dam in discharging at any time such volumes as may be desired. As the dam is to be operated with a head on either side, all gates are constructed to act under a direct or a reversed head.

The movable dam adopted for the log-sluice and navigable pass, was the Lang type of the original, or White's, bear-trap gate, with special features for the purposes herein set forth.

The main features of the dam may be briefly described as follows:

It is built of cribwork of 12″ x 12″ pine filled rock and rests on a pile foundation. Commencing at the left bank or south side, we have first the left pier of the log-sluice which is 16′ wide, 116 feet long, and 16 feet high for the first 73 feet from the upper end, then stepping down 2 feet in 9 feet to a height of 10 feet above the floor. At each end is a wing wall 14 feet long extending into the bank. The upper one is 10 feet, and the lower one 8 feet wide. Then comes the log-sluice opening

11 feet wide, controlled by an improved bear-trap gate. Its base or distance from center to center of hinges is 35 feet. Each of its leaves is 21 feet 6 inches, and its idler is 12 feet long. Its construction is such that the idler may be removed from the free end of the downstream leaf and placed on the free end of the upstream leaf after raising the latter until it overlaps the former. It works then for a reversed head, or a head on the downstream side in the same manner as it did for a direct head, or a head on the reservoir side. It has a range of 11 feet above the floor. Next is the right hand log-sluice pier, 12 feet wide, 68 feet long, and 16 feet high, to which is connected the cribwork of five small sluices. This is 34 feet wide, 18 feet long and 16 feet high and is connected on the right with the left hand pier of the navigable pass. Each of these small sluices is 5 feet wide and 4 feet high, controlled by sliding gates in slots, and are operated by worm-gear machines. The left hand pier of the navigable pass is 12 feet wide, 17 feet high, and 249 feet long. Again comes the navigable pass 249 feet long. The pass is controlled by two improved bear-trap gates. Of the length, 249 feet, the fore bay takes up 20 feet, the upper gate 22 feet $3\frac{1}{4}$ inches, the lock chamber 159 feet $8\frac{3}{4}$ inches, and the tail bay 20 feet. Lastly is the north shore pier or right hand pier of the navigable pass. It is 17 feet high, 16 feet wide, and 249 feet long, with wing walls similar to those for the south shore pier.

The walls of the log-sluice and navigable pass are lined with 3-inch plank up to the flowage line. The edges of the plank have $\frac{1}{2}'' \times \frac{1}{2}''$ grooves in which are inserted $\frac{1}{2}'' \times 1''$ tongues of seasoned pine. The elevation of the floor of the log-sluice and five small sluices is 1209 feet above sea level, which is about the level of the river channel. The elevation of the floor of the navigable pass is 1208 feet, that of the flowage line 1220 feet, and the top of the cribwork 1225 feet above sea level.

SHEET PILING.

The following are the principal lines of sheeting in the foundation:

There is a line of sheeting extending all around the foundation, and two lines forming diaphragms into the banks from the shore piers. At a distance of $18\frac{1}{2}$ feet from the upper end of the dam, a line of triple-lap-sheeting extends across the foundation, and forms the upper sides of the recesses underneath the log-sluice and upper navigable pass-gates. It is also continuous around the recesses of those gates and around that of the lower navigable pass-gate. These sheet piles were made by fastening together three $2'' \times 12'' \times 16'$ oak plank, allowing the middle one to project out 2 inches, thus forming a tongue on one side and a groove on the other. They were driven with an 1800 pound hammer

and a jet of water from a steam force-pump. Their penetration was from 12 to 14 feet. The material in the foundation is sand, gravel, and some pockets of blue clay.

FILLING BETWEEN AND UNDER CAPS AND BEHIND PIERS.

The space behind piers and between and under caps was filled with material taken out of the foundation, except where concrete was used.

CONCRETE.

The spaces between and under caps in the depressions underneath the log-sluice and navigable pass-gates were filled with concrete. For a distance of 20 feet below the hinges of the lower leaves, and for the same distance above the hinges of the upper leaves, concrete to the depth of 6 inches was put in, excepting a space of about 4 feet next to the hinges of the lower leaves, where gravel was used. The concrete was made of 1 part Louisville cement, 2 parts clean sharp sand, and 4 parts gravel.

CAPS IN FOUNDATION.

The caps under the piers are 12″ x 12″ timbers drift bolted on the heads of the piles. Elsewhere they consist of two 6″ x 12″ timbers screw-bolted to a 6-inch tenon, 12 inches long. At the anchorages the tenons are dovetail in form, being 5 inches thick at the neck and 7 inches at the end. Between the caps in the recesses there are 6″ x 12″ blocks wedged tightly so as to hold the anchorage caps to their work when under an upward strain.

FLOORING.

The flooring of the dam, excepting for 20 feet above and below the gate hinges, consists of two courses of timber. The lower one is 6 inches thick and is fastened to the caps with ½″ x 14″ boat spikes. The second one is 3-inch plank spiked with ⅜″ x 7″ boat spikes. The 3-inch plank in the recesses have ½″ x ½″ grooves in the edges, in which are inserted ½″ x 1″ tongues of seasoned pine. The timbers to which the leaves of the gates are hinged are of white and Norway pine, and are 20 feet long. They form the floor for that distance above and below the hinges. Those in the navigable pass are 11″ x 12″ x 20′, boxed 2 inches on the caps, are screw-bolted together with three lines of 1″ x 24″ bolts, and drift bolted to the caps with 1″ x 20″ drift bolts of round iron. The gains extend 2 inches on each side of the caps for the purpose of keying the timbers to resist a pull or push. After the flooring was laid it was caulked with oakum and cemented under pressure. A 2½″ auger hole was bored about 2 inches in the 3-inch plank, and then through the

rest of the floor with a 2-inch auger. Then a gas pipe 16 feet long was inserted, and through it hydraulic liquid cement was injected.

FLUMES.

In the right hand pier of the log-sluice and in each of the navigable pass piers, are flumes extending from end to end of piers. Each flume is connected with its recess under a gate by a port of suitable dimensions for the purpose of operating the gates by the water pressure due to the head in the pond. Each flume is flared out at the ends in which are grates of $\frac{1}{2}''$ iron to prevent anything larger than an inch in diameter from centering. The floor of the dam is the floor of the flumes, and the construction is such that there can be scarcely any leakage through them when the water in them is under pressure. They are 2 feet high. The available sectional area of the log-sluice flume is 2.83 square feet and that of each of the navigable pass flumes 4.83 square feet.

VALVES.

The flumes at the ports are controlled by circular valves revolving on horizontal axes. On each valve shaft is a large sprocket wheel connected with a small one on a frame at the top of the pier with a combination of chains and rods. On the shaft of the smaller wheel is a 6 foot power wheel for the purpose of operating the valve. The valve is so constructed that when it completely closes the flume on one side of the port, the opposite side is entirely open. Again, as the valve is revolved, for each increment that the flume is opened on one side, the opposite side is closed by a like amount.

NAVIGABLE PASS GATES.

As previously referred to, the navigable pass is controlled by two improved bear-trap gates of the Lang type with some special features. The special feature of these gates is that for a direct head or a head on the lake side, they act as improved bear-trap gates; but for a reversed head they act as old bear-trap gates. The accompanying drawing shows a section through the lower gate when it is up full height as an improved bear-trap gate; also its position when up full height as an old bear trap, and its position when down on its bed. The plan shows the gate lying on its bed.

The valve is shown completely open on the upstream side, thus connecting the recess underneath the gate with the pond. This brings the full pressure due to the head underneath the gate, and its crest will rise to or above the water in the pond, provided the head is greater than that which it takes to start it from its bed. This is true whether it is acting as an improved or as an old bear trap gate. To let the gate down the

valve is turned until the flume is completely closed on the upstream side, and completely opened on the downstream side. The water thus escapes from underneath the gate to the pool below; and, as it is relieved of pressure, it falls until it reaches its bed. For every intermediate position of the valve there is a corresponding head underneath the gate, and the crest of the weir moves accordingly. This enables us to use a gate as a weir discharging any desired depth of water over its crest. The position of the valve for a given flow over the weir is found by trial. The upper gate is similar in all respects to this one, excepting that its base is shorter.

As shown by the drawing, each gate is formed of an upstream and downstream leaf, and a flap or idler. The upper ends of the upstream and lower ends of the downstream leaves are hinged to the floor of the dam with strap hinges on every other timber, excepting the two last ones on the north side, where both timbers have hinges. One end of the idler is hinged to the free end of the downstream leaf and laps and slides on the upstream leaf. To reduce the friction, 5-inch rollers with ¾″ journals are placed in the ends of idlers every two feet. Each idler of the navigable pass gates is also provided at the ends with ten valves, 2½″ x 5″ which revolve on horizontal axes to allow the leakage through the chain holes between the boxes and elsewhere to escape and not act as a weight on the upstream* leaf when the gate is acting as an old bear-trap gate. Their specific gravity is slightly in excess of water, and while the gate is acting as an improved bear trap they are down, and leave no opening at the end of the idler; but under a slight pressure from the opposite direction, it opens. In the timbers in which they are placed slots are cut out for a short distance corresponding to its sectional area. Three-eighths holes were bored in the idler timbers near the hinges to create an air pressure between the idlers and upstream leaves when the gates are acting as old bear-trap gates. The valve is shown in plan in the drawing marked *V*.

The length of the base of the upper gate is 22 feet 3¼ inches from center to center of hinges, and that of the lower gate 27 feet. The upper and lower leaves are each 13′ 9⅜″ long, the timbers of the upper leaf being 8″ x 12″ and that of the lower 9″ x 12″ white pine. The timbers of the upstream leaf of the lower gate are 8″ x 12″ x 16½′, and that of the downstream leaf 9″ x 12″ x 15′ 7½″ white pine. The idlers of both gates are of oak. The timbers in the idler of the upper gate are 4¼″ x 12″ x 9′ and those in the idler of the lower gate 4¼″ x 12″ x 11′ 5½″. Both of these gates have a rise of 12 feet above the floor of the pass.

* The terms upstream and downstream leaves always refer to such as they are with reference to the direct head.

The timbers of all the leaves including the idlers are screw bolted together with three lines of screw bolts each 2 feet long, one line at the middle and one near each end. There are also in the joints dowels of round iron 2 feet apart. The screw bolts and dowels in the downstream leaves are of 1″ iron; those in the upstream leaves $\frac{7}{8}$″; and those in the idlers $\frac{3}{4}$″ iron. At the free ends of the downstream leaves just below the idler hinges, are two continuous straps of $\frac{1}{2}$″ x 4″ iron on opposite sides bolted together every foot of length by two $\frac{5}{8}$″ bolts. They were put on to bind the timbers of the free ends more firmly together.

To prevent leakage between the timbers of the leaves and idlers, tongues of $\frac{1}{2}$″ x 1″ seasoned pine were inserted in corresponding $\frac{1}{2}$″ x $\frac{1}{2}$″ grooves in the sides.

The side timbers of the leaves have from $\frac{1}{2}$″ to $\frac{3}{4}$″ play at the walls. Oak cleats $1\frac{1}{2}$″ x 5″ with the side next to the wall beveled, were screw bolted to the side timbers with $\frac{5}{8}$″ bolts. After they were bolted on, a saw was run through between the cleats and the walls, leaving a clearance of $\frac{1}{8}$″ to $\frac{3}{16}$″. The same amount of clearance was left at the sides of the idlers, but cleats were not used on them.

The blank timbers in the leaves at their lower ends are connected with the hinged timbers by means of 4″ x 12″ x 18″ oak blocks. These blocks are screw bolted with four 1-inch screw bolts to the blank timbers and lap 3 inches on the adjacent timbers. This transfers the strain due to the pressure on the blank timbers to the hinged timbers. Similar blocks connect the free ends of the blank timbers in the upstream leaves with the adjacent timbers. In this case, however, the bolts pass through the ends of the oak blocks into the hinged timbers. This is to resist the opposite pull of the chains when the gate is up full height as an improved bear trap.

The free ends of the leaves are connected by $\frac{3}{4}$″ chains 2 feet apart, adjusted as to length so that when the gates fold to their beds there is no appreciable slack. In each of these gates is another set of chains of $\frac{5}{8}$″ iron 2 feet apart, connecting the heel of the down stream leaf with the free end of the upstream, to prevent the latter from leaving the former when the gate is acting as an old bear trap The free end of the upstream leaf is provided with $5\frac{1}{2}$″ rollers with $1\frac{1}{8}$″ journals to reduce the friction between the two leaves while the gate is acting as an old bear trap.

The ends of the timbers in the floor to which the hinges are attached, are anchored to the caps of a row of piles next to the triple lap sheeting by $1\frac{3}{4}$″ bolts 2 feet apart. There are also 1″ screw bolts going through the first cap below the triple lap sheeting. Besides this there are six-inch timbers bolted with drift and screw bolts to the triple lap sheeting. After they were bolted, wedges of hardwood were driven under them, so that when a lift comes on the caps the sheet piling comes into play to resist the upward force.

After the gates were completed a line of three-inch plank was placed at the ends of the timbers to which the lower hinges are attached, the space inside was filled with gravel, and then a liquid hydraulic cement was forced through a 16-foot gas pipe. This was done to cut off the lift on the ends of the timbers when the lower leaves are under pressure. To guard against the effects of a slight lift of the timbers to which the hinges are attached, a slot 2″ x 6″ is cut in each timber just over the triple lap sheeting so as to allow any water to escape in case such should occur. About half way between the first two caps below the hinges a two-inch auger hole was bored in each timber to further facilitate the escape of water that might come from the recess. The chains connecting the heel of the downstream leaves with the free ends of the upstream ones, are provided with turnbuckles at their lower ends; and in adjusting these chains the gates were raised full height as an old bear-trap gate by means of jackscrews, when a uniform tension was put on the chains. By means of tackle the downstream leaves were next raised up full height, when the short chains were subjected to a uniform tension. This was done by means of the staples in the free end of the downstream leaves.

To cause the short chains to draw out of the slots between the boxes of the rollers when the gate is acting under a reversed head 32 pound weights of cast iron were attached to them. It was found by experiment that it required 28 pound weights. After the chains were adjusted the gates were lowered to their beds, and the water in the coffer-dam was allowed to raise over them. It was found that the upstream leaves would not float and that the lower ones would not sink. To change the specific gravity of the upstream leaves, spruce planks were attached near the free ends until they floated. After the idlers were put on, railroad iron was laid transversely across the downstream leaves until the gate would sink in still water. The next test made was to determine the head required to raise each gate from its bed when acting as an improved bear trap. It was found that a static head of 2 inches would raise the upper gate and 3 inches the lower one. No test was made as to the head that would raise the gates while acting as an old bear-trap, as this was impracticable. There has been no opportunity thus far to test the working of the gates under all conditions of backwater.

For the conditions of an old bear-trap gate, the leaves of the upper gate bear such proportions to the base, that on the assumption that the gate has a specific gravity of 1, the downward force when water is passing over it when it is down is 0.98 of the upward pressure due to the head; and under similar conditions the downward force is 0.74 of the upward force in the lower gate. It may be noted here that this ratio is a maximum when the gate is down. The lower gate is therefore much more sensitive to a head as an old bear trap than the upper one.

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AIR BAGS AND CAPSTANS.

When the head is less than two or three inches, or so small that it will not raise the gates, provision was made to raise them above the water so that water may be held on either side of the dam by means of air bags and capstans, either of which is sufficient to raise them. In the navigable pass gates there are attached to each of the upstream leaves four air bags, each 8′ 10″ long and 2 feet in diameter. Each air bag is connected with an air pump on top of the pier with a half inch hose through which air is forced into the bags for inflation. The pipes and valves at the air pump are so arranged that all the air bags may be simultaneously inflated, or one or more may be inflated independently of the others. These air bags are made of 2-ply special woven 16 ounce duck, heavily coated with pure Para gum. In case the air bags should fail, each gate is provided with two powerful capstans which can be connected with $\frac{3}{4}$″ chains 12 feet long attached to the free ends of the downstream leaves near the sides. Two similar chains are attached 10 feet from the sides, which can be used with derricks should occasion require it.

In the left hand pier there is a 2′ x 3′ flume extending across the pier and intersecting the main flume at right angles. This flume is controlled on each side of the main one by two sliding gates. The object of it is to assist if desired in filling or emptying the chamber. In the right hand pier there is a 2′ x 3′ flume connecting the chamber with the main flume, and is controlled by a sliding gate. The purpose of this one is to assist in emptying the chamber if desired.

Both gates of the navigable pass were made slightly heavier than water, so that when there is no head both gates will fall by their own weight and allow the passage of boats.

In locking a boat upstream it is first brought into the lock. Then the valve of the lower gate is opened upstream, the inside gate in the left hand pier is opened, that in the right hand pier closed, and at the same time the upper gate is lowered so as to allow the water to spill over the crest in any desired amount until the chamber is full. When the chamber is nearly full the upper gate falls. It may be caused to fall sooner if desired by opening the valve completely on the lower side, thus reducing quickly the pressure underneath, until it falls to its bed. When it is down the pressure on it is that due to the head. To lock a boat down, the valve of the upper gate is closed on the downstream side and the crest of the gate raised to the surface of the water by means of the air bags or capstans. Both gates in the 2′ x 3′ flume intersecting the main flume in the left hand piers, and that controlling the 2′ x 3′ flume connecting the chamber with the right hand pier, are opened. At the same time the lower gate is lowered so as to allow a spill over the weir until the chamber is empty and the gate falls to its bed. The lock may be operated

without the use of the small flumes connecting the chamber with the main flumes by filling and emptying the chamber by a discharge over the gates. Further, when the chamber is full, the upper gate may be raised without the use of either the air bags or capstans, by closing its valve on the downstream side and dropping the lower gate until there is a head of about 2 inches on the upper one, when its crest will rise to the surface. Care, however, must be taken that too great a current is not created in the chamber if a boat is in.

The design was made under the direction of Major W. A. Jones for a board of engineers consisting of Major Amos Stickney, Major Alexander Mackenzie, and Captain W. L. Marshall, who recommended its approval to Brig. General Thomas L. Casey, who approved it June 30, 1893.

During its construction I was in local charge. It was completed in October, 1895.

In conclusion I would say that the improved bear trap herein described is the first of this type that was built where the conditions of backwater are variable. In all other cases it was built on a weir or what was equivalent to a weir.

IV. Marshall's Bear-Trap Dams.

By W. L. Marshall, Major, Corps of Engineers, U. S. A., Member Am. S. C. E.

I am glad that the subject of bear-trap dams has been brought up for discussion in a Society of Engineers by so carefully prepared a paper as this of Mr. Powell. For years I have been of the opinion that the best solution of the problem of movable dams will be found in the principle of the so-called American bear-trap dams.

In August, 1889, while I was studying the subject of movable dams for application of some type to Rock River, Illinois, Mr. Parker brought into my office, in Chicago, a model of his recently patented improvement and exhibited it to Brig. Gen. Thos. L. Casey, then Chief of Engineers, U. S. Army, who happened to be on a tour of inspection of my works, and myself.

The General was much interested, and suggested to Mr. Parker the advisability of making the sections of the upstream leaf of unequal width, with a narrower upper section and idler, and myself and some of my assistants, independently, suggested to him the evident possibility of making "the idler" a working part of the device. In subsequent

patents Mr. Parker adopted the unequal sections of upper leaf. The other suggestion was adopted, independently discovered, by Lang, and covered by patent to him.

The Parker and Lang improvements are most valuable, and they directed towards the hinged leaf system my efforts to solve the bear-trap problem.

After discarding the idea of utilizing the idler as a working part of the dam, I adopted the Parker principle in preparing plans for the Illinois and Mississippi Canal, for a movable dam with 100 foot passes, and sluiceways in dams on Rock River. Detailed drawings (now known to be defective in design) of Parker gates were submitted by me to the Chief of Engineers, U. S. A., in June, 1890. Afterwards, in September, 1895, about the time when Mr. Powell prepared his paper, now under discussion, modified forms of bear traps suggested themselves to me. These involved the hinged leaf principle, with the flexible qualities of quadrangular prisms for hydraulic chambers instead of the more rigid triangular forms in use, which, upon analysis, although differing much in form, are so nearly related that they may be described in the same category. I have been requested by Mr. Powell, and by the Secretary of the Civil Engineers' Society of St. Paul, to give drawings, descriptions and mathematical analyses of these gates as part of the discussion, and in the time allowed, with the assistance of Lieut. Henry Jervey, Corps of Engineers, U. S. Army, who has performed the mathematical work relating to both forms of the "Marshall" dam, I am enabled to submit such descriptions, analyses, and outline drawings as will enable any engineer to construct them.

All hitherto known forms of modified bear-trap dams, viz., the "Carro, Girard, Parker, and Lang," have their leaves attached together at the crest of the dam, and their hydraulic chambers triangular prisms, when the dams are at full height. In the "Girard, Parker and Lang" types, with hinged leaves, in intermediate positions the hydraulic chambers are quadrangular prisms, with one re-entrant angle projected into the hydraulic chamber.

In the "Marshall" gates (Plate B) one leaf projects beyond the line of attachment of the two leaves, at least one-half the width of the projecting leaf. The hydraulic chambers are in all cases quadrangular prisms with salient angles, or the joint in the downstream leaf is always projected out from the hydraulic chambers and downstream from the lower foundation hinge. The joint always forms a knuckle downstream. There are no restraining chains or stops, but the ultimate positions of the gates are determined by equilibrium of water pressure and weight of gates only.

When the downstream leaf is extended above the upstream leaf

(Plate B, Fig. 1) the combined width of the two sections of the downstream leaf should be equal to, or less than the width of the upstream leaf; the line of attachment of the two leaves should be at, or slightly below the middle line of the downstream leaf (counting both sections), or at, or slightly below the lowest possible center of pressure of the water on the upper section of the downstream leaf, but above all possible centers of pressure on the downstream leaf, including both sections.

The lower section of the downstream leaf is always to be, as near as practicable, equal in width to the distance from the downstream knuckle to the line of attachment of the two leaves.

The hydraulic chamber, therefore, in this form (No. 1) is always a quadrangular prism with salient angles, inasmuch as the angle at the knuckle can never become as great as 180 degrees, with a reasonable fall over the dam. The sides of this prism are equal two and two in width, but the sets of two unequal. The equal sets of two sides in this form are connected together, with the vertex of the wider set upstream, at foundation.

In this form, not only does the gate rise by the pressure of the initial head on the components of the downstream leaf forming part of the hydraulic chamber, but also from the direct pressure of the water in the upper pool on the projecting surface of the downstream leaf, and the gate will rise as fast as the hydraulic chamber may be filled. Whatever be the height of water above the crest of the dam, or the extent of backwater, as long as the exit of the hydraulic chamber is closed and the inlet open, the center of pressure upon the downstream leaf will fall below the hinged axis of attachment of leaves, and, consequently, the downstream knuckle angle will project from the hydraulic chamber. As the backwater rises the gate will rise, and in case the dam is allowed to be totally backed out with but a slight current over it, the gate will reach its maximum height and occupy such a position of unstable equilibrium that a rapid opening of the outlet valve to full extent, and closing the inlet, might possibly result in a reversal and failure of this gate; *i. e*, as the backwater rises the gate becomes more and more difficult to lower, or the moments of the lifting and depressing forces become more nearly equal, and at the extreme, when entirely submerged, if it be not made heavier than water, the gate cannot be lowered at all. If made heavier than water it will then fall flat. Ordinarily the backwater will not be allowed much above the half height of the dam, and under these conditions, or with any working or appreciable head, it is easily worked and lowered, but on account of its form, which involves an apron above the dam to prevent drift accumulations, and a motion of its crest upstream in lowering, but little value is assigned to this form of the "Marshall" bear trap, in comparison with the design

No. 2. It is believed, however, to be comparable in utility to forms that are in use, and in special cases superior in some respects to them.

In the second form of this invention (Plate B, Figs. 2 and 4) the *upstream leaf* is extended one-half its width beyond the axis of junction between the leaves. The downstream leaf is in two unequal sections, hinged together, with downstream projecting knuckle, and is hinged to the upstream leaf and foundation so as to form a hydraulic chamber in the form of a parallelopipedon, with its longer sides respectively coincident with and parallel to the base of the dam or plane of foundation hinges; the shorter sides being in width equal (as nearly as practicable for material forms) to one half the width of the projecting leaf.

This form differs from all previous forms in this—that the resultant of all forces acting on the dam to move it bodily, is directed downwards through the base of the dam, to insure stability, and not upwards to overturn it, or to require heavy foundation anchorages *; also that all

* In all forms of bear-trap dams having the downstream leaf constituting the dam, the pressure on the dam is directed obliquely upward, to tear the effective leaf away from the foundation. In these dams, properly speaking, there is no hydraulic chamber. In raising the dam the upstream leaf is simply a screen to allow the water in the upper pool to be gradually applied to the downstream leaf, and a governor or restraint upon the motion of this leaf. When the dam is raised to full height the upper leaf is simply a tie to hold the gate against overturning, and must be anchored to the foundation.

This anchor may be the weight of water on the foundation, or a mass of masonry underneath the foundation, or the abutment walls on top the foundation. In lowering such dams the greater pressure is transferred to the upstream leaf, and the dam is removed, but still there must be anchorage to foundation, till the dam is thrown down.

In Marshall's dam No. 2, the upstream leaf forms the dam. The pressure thereon is always, whether in rising or falling, obliquely downward. The hydraulic chamber is below the dam, in the lower pool, and is a veritable closed hydraulic press, the distention of which raises the dam and the collapse of which allows it to lower. The weight or mass of water on the foundation above or below the dam is not a factor in the case. Steam, air, gas or anything producing distention of the closed chamber will raise the dam, and the water pressure of the upper pool is not at all restrained in its direct action on the dam.

It is only necessary that the hydraulic chamber have tight, strong sides and joints, and the dam as a whole be prevented from sliding down stream on the foundation. There is no tendency to pull the dam away from the foundation.

To get a clearer perception of these facts, imagine the upper and lower pools to be separated by an absolutely water-tight diaphragm extending below the bottom edges of the effective leaves or dams when raised.

In this case in triangular dams the so-called hydraulic chambers form parts of the upper pool; in Marshall's No. 2 of the lower pool. By leakage through floors or otherwise the hydraulic pressures under the hydraulic chambers will be equalized with that in the pools in which respectively the hydraulic chambers are located.

movements of all parts of the dam are downstream in lowering it, and, consequently, the lowering of the dam can never possibly be interfered with by accumulations of ice or other drift.

Both forms of "Marshall's" bear-trap dam depend upon the principle that if any obliqued angled quadrangular prism having its sides equal in sets of two, the sets unequal, be subjected to external pressure on its sides directed inwards, it will collapse or fall flat, the longer sides approaching each other. If subjected to an internal pressure directed outward, the sides will move apart (or rise) until the interior volume of the prism becomes a maximum, which will occur when the shorter sides are perpendicular to the longer sides.

If subjected at the same time to an internal pressure directed outwards, equal upon each superficial unit of interior surface on opposing sides, and to an external pressure on one side directed inward, the prism will take some position between its maximum and minimum volumes.

The triangular dams under such conditions will turn over down stream if not securely anchored to the foundation above, and be destroyed as dams.

The Marshall No. 2 will require only restraint against sliding down stream.

In triangular dams there must be anchors to hold down the dam, which is the downstream leaf, and sheet piling under it, to prevent undercutting in the direction of flow.

By careful sheet piling above the base of the so-called hydraulic chamber in triangular dams, and perfect sub-drainage of foundation into the lower pool to prevent equalization of pressures above and beneath the hydraulic chamber (so-called), the weight of water may suffice on stiff floors for anchorage. This practically makes the foundation of the dam and the sheet piling under the dam a necessary part of the dam or of the downstream leaf, but the foundation is parallel to the restrained current, and cannot in any sense constitute a "dam" or part thereof. If now from any cause this sub-drainage becomes clogged or ineffective then the dam may be destroyed, or depend for stability upon the weight of artificial masses or upon the weight and transverse strength of the floor system upstream from the effective leaf of the dam. It is assumed in the text that the leaf which (with subsheeting directly in continuation of it) obstructs by most direct means the horizontal motion of the water, constitutes the dam.

In Marshall's No. 2, the dam is the upstream leaf, with sheet-piling to prevent undercutting. The hydraulic chamber is simply a motive power, and its action is as positive as that of any lifting jack or press, that may be independent of the weight or body lifted. The stability of the dam is in no wise dependent upon the internal pressures within the lifting jack or hydraulic chamber; nor upon its weight nor upon differential pressures on its sides, and this constitutes the material difference between Marshall's No. 2, and all other forms of Bear-Trap dams, as claimed in the text. In this connection attention is invited to Plate B, Fig. 4, where it is distinctly shown that the hydraulic chamber is simply a strut or prop under the dam when at rest, and a lifting jack when in motion, that may not be attached to the dam at all, further than at lowest points to prevent separation of joints by floatation, or to insure constant contact between joints of the hydraulic chamber.

In Form No. 1 of this dam, if the material be of no weight, the maximum height of dam corresponding to the maximum practicable volume of the hydraulic chamber will occur when the dam becomes submerged, or the backwater at or above the crest of the dam, and but little or no fall over it. The minimum height raised will occur when there is no backwater at all and the water in upper pool just at the crest of the dam.

In the latter case the height of the dam above the plane of foundation hinges will be 75 per cent. of the distance between these axes. In the former it will be about 91 per cent. of this base.

In Form No. 2 the ordinary height of dam will correspond with no backwater. As the backwater rises the gate will also rise until the backwater reaches the surface of the upper section of the lower leaf. It then, as the backwater rises, slowly lowers till submerged.

This form will not rise at all unless the upper section of the downstream leaf exceeds in width two-thirds the width of the upstream leaf. The relations between the angle of rise, and the width of leaves when there is no backwater is expressed by the equation $Z = \frac{2\,X}{3\,\cos\alpha}$ in which

Z = width of upper section of downstream leaf,

X = width of upstream leaf,

α = angle of rise between upstream leaf and plane of foundation hinges.

Where α equals 45 degrees then Z equals .943 X, and the height of the gate will be 75 per cent. of the distance between the hinges, as in the first form with no backwater. It is considered better to make the upper sections of the downstream leaf in width equal to or greater than the width of the upstream leaf in order to increase the angle of rise, or rather the lifting force. The advantageous angles of rise vary between 45 degrees and 65 degrees. Angles less than 60 degrees are not advantageous when constant backwater rises much above the upper section of downstream leaf. The height of dam may be regulated by the supply and exit valves between its maximum and minimum angles, and it is well to provide for a greater force than necessary to maintain the dam at the required height, to guard against unforeseen or indeterminate depressing forces. It would be well to proportion the upper section of downstream leaf for an angle say, 5 degrees greater than it is intended to keep the dam, to provide sufficient margin.

There are several remarkable features to be observed in this form of dam. The mathematical relations of its parts depend upon the properties of parallelograms, and are, therefore, such as to make all calculations of stresses and dimensions extremely simple; the angles are such that packing all joints where leakage can occur except at the one acute angle at the downstream knuckle, is easily and cheaply effected. The

flexibility of both forms is greater than can be found in any other form of bear-trap dam. No sudden strain can possibly be brought upon any part of either form of the dam, and anything like the action of a hydraulic ram is impossible. In all other forms ramming action is possible, and chains or other stops are necessary, which, without care, may be carried away or broken.

Attention has already been called to the fact that the resultant of all forces acting on the effective leaf of Form 2 is toward and through the foundation; not upward, or from it. There is also another peculiarity of Form 2, *i. e.*, the horizontal force acting to push the system downstream, or to lower the dam, as long as there be no backwater, and as long as the upper pool reaches just to the top of the upstream leaf, is constant and equal to the pressure on that leaf when it stands vertical with water at its crest, and no backwater. This form is believed to be the most sensitive and responsive of all bear traps; the effective lifting moment in proportion to the depressing moment of available head is a maximum at the lowest position of the gate; a minimum at the highest when the moments become equal. The horizontal depressing force as shown, is constant, at all angles of rise, except that when there be backwater, or still water, rather, it is necessary to depend upon its weight to close it down flat, as in the case of all bear traps. The objection to this form is the vertical fall from the crest of the dam to the upper surface of the lower leaf, and the possibility of drift accumulations in the acute angles below the crest. Where this objection is good the usual resort to inclined downstream aprons (which need not be heavy) may be taken. In many cases of clear water streams, and in raised sluices, the aprons may not be found necessary.

The great difficulty in all bear-trap dams is to move the gates when entirely submerged. When there is a sufficient current or fall over them to create an effective hydraulic head due velocity these gates may be raised and lowered even when made of equal, or somewhat greater or less specific gravity than water. It is not likely even if made of metal, that the weight to be moved will be greater than equivalent to a six-inch head of water which is produced by a current somewhat less than six feet per second. In slack water and moderate currents it is better to make the gates heavy enough to readily sink to rest, and to supply a working head either by taking the water through conduits leading a sufficient distance above the outlet, or else to provide an auxiliary head by reservoir on the bank or otherwise.

Some bear-trap dams, particularly of types like the "Lang, Carro, and Du Bois," on account of the necessity for rollers to diminish sliding friction in lowering, offer joints through which there may be much leakage from the upper pool into the hydraulic chamber, and have been

made with such restricted outlet ports that the dams cannot be lowered below a certain level.

In any type the ports should be made capacious, so that a very small head will cause a greater flow out of the hydraulic chamber than can possibly leak into it from the upper pool, under any head that may be encountered in lowering the dam, and to discharge a sufficient volume under minute heads, such as the weight of the gate in slack water.

In Form No. 2 of the "Marshall" dam the joint at the foot of the upstream leaf is of such angle always that it may be made nearly absolutely water tight by a covering strip of sheet rubber packing. The joint next the abutment is less than one-half the development of any other type of bear-trap dam. Comparative drawings are given herewith that show the materially less volume of hydraulic chamber in the "Marshall" dam than in the triangular forms. Ports, therefore, of any definite size will supply a "Marshall" dam when they will not suffice for any dam of the usual form of the same height and length of crest. Both forms give higher dams in proportion to distance between foundation supports than any other type, which may be as easily worked.

Instead of hinging the leaves of Form No. 2 rigidly together, which requires very careful adjustment of four parallel axes of rotation, and will also bring tensile stress on the upstream leaf and also on the lower section of downstream leaf, the gate may be made without any hinges permanently attached to the leaves at junctions, but with quoins only, and limiting straps.

Fig. 4, Plate B, represents this arrangement by which the upper section downstream leaf is kept parallel with the plane of the lower axes of the gate by parallel eyebars. These eyebars take all the tensile stresses in the system, and the actions of the forces on the leaves themselves result in pressing them together along quoins or sockets of junction, thus making possible absolutely water-tight joints throughout the system without packing of any kind.

The construction permits long horizontal leaves of light construction by reason of the intermediate supports which may be increased in number.

In this method of construction it is only necessary to provide such straps, collars, or ligatures as may prevent the parts separating so far as to fall out of the sockets or quoins. Quite free play may be safely allowed, and the difficulty incident to all hinged leaf bear-trap dams of constructing four parallel continuous axes, may be largely avoided.

It is necessary to have the foundation quoins parallel and the leaves exact rectangles. The eyebars need be of exactly the same length, etc., but it is not necessary that all the forward or all the rear eyebars

lie in a plane. The points of attachment of each bar to leaf and foundation must properly correspond, so that equal sectors of circles shall be described by the bars and the resultant upward pressure on the horizontal leaf pass midway between the eyebars, in any given section of the dam.

It is evident that if the leaves be heavier than water (so that the upstream leaf may not float out of its quoin at bottom), no rigid connections between the leaves will be required—the eyebars being the only neccessary attachments in that case to horizontal leaf and bottom of hydraulic chamber. Collars or straps at ends of gate leaves, similar to what are used at tops of mitred lock gates, are advisable as making the gate more secure against accidental causes of displacement. These collars may allow some play so long as the leaf is prevented leaving the socket. This property of Form 2, by which compressive forces may be utilized to make tight joints in hydraulic chamber, is enjoyed only by this form of bear-trap dam.

Form No. 2, in which the upper section of the downstream leaf moves parallel always to its original position, has suggested to the writer the possibility of building very long dams in sections, the alternate sections being "abutment sections" formed by suspending from the upper section of downstream leaf at the ends thereof, a diaphragm of sufficient strength that rises and falls with the section into a narrow slot prepared below the foundation.

These abutment sections may be raised independently, and the intermediate sections afterwards, or the whole dam of any length whatever be put up at once, all sections rising nearly simultaneously. The full details of this arrangement are too voluminous for this paper, and have not been sufficiently perfected for publication as yet.

The drawings and mathematical discussion by Lieut. Jervey, Corps of Engineers, U. S. A., appended hereto, will fully explain these new types of bear-trap dams.

In designing them, more careful attention must be given to these analyses, in Form No. 2 especially, and to carefully proportioning the relative dimensions, than in other forms of bear-trap dams, because their limits of rise, etc., are fixed or determined by the natural forces acting on the dams, and not in any way restricted by the introduction of outside resistances or stops.

MARSHALL'S BEAR-TRAP DAM, NO. 1.

MATHEMATICAL ANALYSIS.

By Henry Jervey, First Lieutenant, Corps of Engineers, U. S. A.

Refer to figures on Plate A, 1 to 8 inclusive.

Denote lengths of upstream leaf and of lower and upper sections of downstream leaf by X, Y and Z, respectively.

Let X be attached to Z, so that Fig. 1, $FE = EG = Y$, and let $DG = X$.

Let θ, θ' and φ represent the angles shown in Fig. 1.

Under the conditions mentioned we may readily deduce the following equations:

$$\sin \varphi = \frac{2 X \sin \theta (X \cos \theta + Y)}{X^2 + Y^2 + 2 XY \cos \theta} \qquad (1)$$

$$\cos \varphi = 1 - \frac{2 X^2 \sin^2 \theta}{X^2 + Y^2 + 2 XY \cos \theta} \qquad (2)$$

$$\sin \theta' = \frac{(X^2 - Y^2) \sin \theta}{2 XY \cos \theta + X^2 + Y^2} \qquad (3)$$

from which corresponding values of φ and θ' may be deduced for all values of θ, which is assumed to be the independent variable.

If (Fig. 1) we make the further assumptions that $X = 4 Y$ equations (1), (2) and (3) reduce to

$$\sin \varphi = \frac{8 \sin \theta (4 \cos \theta + 1)}{17 + 8 \cos \theta} \qquad (4)$$

$$\cos \varphi = 1 - \frac{32 \sin^2 \theta}{17 + 8 \cos \theta} = \frac{8 \cos \theta (4 \cos \theta + 1) - 15}{17 + 8 \cos \theta} \qquad (5)$$

$$\sin \theta' = \frac{15 \sin \theta}{17 + 8 \cos \theta} \qquad (6)$$

To determine the position of equilibrium of the rising and falling bear-trap dam under consideration, let us make the following additional assumptions to apply in every case:

1. That the surface of water in the upper pool remains constantly coincident with the crest of the dam.
2. That the leaves of the dam may be reduced to surfaces, having neither weight nor volume.
3. That friction may be neglected.
4. That $w =$ weight of 1 cubic foot of water.
5. That $Z = 3 Y$.

CASE I.—DAM RISING.

Hydraulic chamber in communication with upper pool only.

Under such conditions the water pressure will be the same on both sides of X (Fig. 1), and may be neglected in this discussion; the pressures on Z and Y are the only forces tending to produce motion in the dam.

(a) When there is no backwater, Fig. 2:

P_1 acts at F, (EF being $\frac{1}{3}$ EB) and

$$P_1 = \frac{3\ Yh''\ .\ w}{2} \tag{7}$$

Pressure on Y has components P_2 and P_3, former has no tendency to cause motion:

$$P_3 = \left(\frac{Yh''}{2} + \frac{Yh'''}{6}\right) w \tag{8}$$

For equilibrium we must have, denoting the lever arm of P_1 cot θ by l, which is equal to $Y \sin \varphi$,

$$P_3\ .\ Y = l.\ P_1\ .\ \cot \theta = P_1\ .\ Y\ .\ \cot \theta \sin \varphi$$

whence, since $h'' = 3\ Y \sin \theta'$ and $h''' = Y \sin \theta$,

and by omitting factors Y and w, we obtain

$$\frac{3 \sin \theta'}{2} + \frac{\sin \theta}{6} = \frac{9 \sin \theta'\ .\ \cot \theta \sin \varphi}{2} \tag{9}$$

Substituting from equations (4), (5) and (6), and reducing, we obtain

$$\cos^2 \theta + .1464 \cos \theta = .2003 \tag{10}$$

Whence $\cos \theta = .3803$ and $\theta = 67° 39'$

$\therefore \sin \theta' = .6921$ and

$$h'' + h''' = .7503\ X \text{ or} \tag{11}$$

Height of crest = .7503 length of base.

(b) When level of lower pool is at E, Fig. 3.

$$P_1 \text{ (as in "a,")} = \frac{3\ Yh''\ .\ w\ .}{2} = \frac{9\ Y^2 \sin \theta'\ .\ w\ .}{2} \tag{7}$$

but

$$P_3 = \frac{Y h''\ .\ w\ .}{2} = \frac{3\ Y^2 \sin \theta'\ w}{2} \tag{12}$$

Substituting in equation (8) of equilibrium, we obtain finally

$$1 = 3 \cot \theta \sin \varphi \tag{13}$$

whence

$$\cos^2 \theta + \frac{\cos \theta}{6} = \tfrac{17}{96}$$

$\therefore \cos \theta = .3693 ;\ \theta = 68^\circ\ 20'$
$\therefore \sin \theta' = .6986$ and
$h'' + h''' = .7556\ X.$

(c) When level of lower pool is at F, Fig. 4.

$P_1 = 2\ Y (h'' - Y \sin \theta')\ w\ .$

$P_a = \frac{13}{12}\ P_1$

$$\mathrm{P}_1 = P_a - P_r$$

$P_6 = \frac{P_1}{12}$

$$P_b = P_a \cot \theta = \tfrac{13}{6}\ Y\ .\ w\ (h'' - Y \sin \theta') \cot \theta \qquad (14)$$

$$P_5 = - P_b \cot \varphi = \frac{Y\ .\ w\ .\ (h'' - Y \sin \theta') \cot \varphi}{6} \qquad (15)$$

$$P_3 = \frac{w\ .\ Y (h'' - Y \sin \theta')}{2} \qquad (16)$$

For equilibrium [compare equation (8)]

$$(P_6 + P_5)\ .\ Y \sin \varphi = P_3\ .\ Y \qquad (17)$$

Substituting values from (14), (15) and (16) and cancelling common factor $Y^2\ .\ w\ (h'' - Y \sin \theta')$, we obtain:

$$\sin \varphi\ (13 \cot \theta - \cot \varphi) = 3 \qquad (18)$$

and by substitution from (4) (5) & (6) and reduction we obtain

$32 \cos^2 \theta + 6 \cos \theta = 3$
$\therefore\ \cos \theta = .22647 ;\ \theta = 76^\circ\ 54'\ 38''.4$
$\sin \theta = .9740$
$\sin \theta' = .7766$
$h'' + h'''\quad .826\ X.$

If $\theta = 90^\circ$, which will occur just as the backwater level reaches the crest of the dam, the dam will attain its maximum height of crest $= .912\ X.$ This position is shown in Fig. 5, which also shows the path of the upper edge of leaf Z as the dam rises or falls.

Referring to the figures on Plate A, it is observed that the forces tending to produce motion become less as the backwater rises in level and reach zero just as the dam is drowned out, leaving the dam in a state of unstable equilibrium and liable to be overturned by a current over its crest if outlets of hydraulic chamber are suddenly opened and inlets closed.

CASE II.—DAM FALLING.

Hydraulic chamber in communication with lower pool through outlet ports.

In actually lowering the dam the inlet ports of the hydraulic chamber would be slowly closed *pari passu* with the opening of the outlets; this is equivalent to a small (differential) discharge from the hydraulic chamber into the lower pool. Inasmuch as any removal of water from the hydraulic chamber, considered air-tight, creates a vacuum therein, this discharge brings an atmospheric pressure on the exterior of the hydraulic chamber, tending to reduce its volume and, therefore, to lower the dam, thus assisting the head of water acting directly on the leaf X; and the total pressure on this leaf is, therefore, due to the difference of level of the upper and lower pools.

a.—WHEN THERE IS NO BACKWATER.

Referring to Fig. 1, Plate A:

Suppose the leaf X perfectly free to move it will follow the receding water in the hydraulic chamber and thus the latter will remain always full. The leaf X will sustain the full head $h'' + h'''$ acting through its center with lever arm $\frac{X}{2}$ to turn X downward about D.

This pressure denoted by

$$P_X = X \,.\, w\,(h'' + h''') = 4\ Y^2 .\, w\,(3 \sin \theta' + \sin \theta)$$

and its moment about D is

$$M_X = P_X\, 2\ Y \,. = 8\ Y^3 .\, w\,(3 \sin \theta' + \sin \theta)$$

The pressure on Z acts at $\frac{FB}{3}$ from F and is due to head

$$\frac{h''}{3} = Y \sin \theta'.$$

Therefore

$$P_1 = 2\ Y^2 \,.\, w \,.\, \sin \theta'$$

and its parallel components at F and E are respectively

$$\frac{5}{3} P_1 = \frac{10}{3}\ Y^2 .\, w \,.\, \sin\ \theta'$$

and

$$-\frac{2}{3} P_1 = -\frac{4}{3}\ Y^2 \,.\, w \,.\, \sin \theta'$$

The sum of the components of these in direction of Z gives the resultant.

$$R_Z = \frac{Y^2 .\, w \,.\, \sin.\ \theta'\,(10\ \cot.\ \theta - 4 \cot.\ \varphi)}{3}$$

and its moment to raise the dam about D is

$$M_Z = R_Z \,.\, X \sin.\ \theta = \frac{4\, Y^3\ .w\ \sin\ \theta\ \sin\ \theta'\ (10 \cot \theta - 4\ \cot.\ \varphi)}{3}$$

which by reduction becomes

$$M_Z = Y.^3\, w\, \frac{20 \sin.\ \theta}{17 + 8 \cos.\ \theta} \left(6 \cos.\ \theta + \frac{15}{2 + 8 \cos.\ \theta} \right)$$

By similar reduction we obtain

$$M_x = 8\,Y^3.\ w \sin.\ \theta\ \frac{(62 + 8 \cos.\ \theta)}{(17 + 8 \cos.\ \theta)}$$

If $\theta = 60°$; $\cos.\ \theta = \frac{1}{2}$; . $\sin.\ \theta = \frac{\sqrt{3}}{2}$ and

$$M_Z = \frac{110}{21}\ Y^3 . w . \sin.\ \theta = 4.54\ Y^3 . w$$

$$M_x = \frac{176}{7}\ Y^3 . w . \sin.\ \theta = 21.77\ Y^3 . w$$

If $\cos.\ \theta = \frac{3}{4}$; $\sin.\ \theta = \frac{\sqrt{7}}{4}$ and

$$M_Z = 3.65\ Y^3 . w$$

$$M_x = 15.61\ Y^3 . w$$

If $\theta = 67°\ 39''$ [See eq'n (10)]; $\sin.\ \theta = .925$; $\cos.\ \theta = .38$.

$$M_Z = 4.86\ Y^3 . w . \qquad M_x = 24.01\ Y^3 . w$$

M_x will always be greater than M_Z.

The dam will, therefore, be easily lowered from its highest position for "no backwater," provided this condition always exists. In lowering an actual dam, however, the backwater would rise relatively to the crest of the dam and, therefore, it is necessary to show that the dam can be lowered for all relative heights of lower and upper pools.

b.—BACKWATER AT F. (FIGS. 1 AND 6, PL. A.)

$$P_x = 8\ Y^2 . w . \sin\ \theta'$$

$$M_x = 16\ Y^3 . w . \sin\ \theta'$$

or by reduction

$$M_x = Y^3 . w \sin.\ \theta\ \frac{240}{17 + 8 \cos.\ \theta}$$

and as in preceding case of "no backwater"

$$M_Z = Y^3 . w\ \frac{20 \sin\ \theta}{17 + 8 \cos.\ \theta}\left(6 \cos.\ \theta + \frac{15}{2 + 8 \cos.\ \theta}\right)$$

If $\theta = 76°\ 54'$ [See eq'n (18)]; $\cos.\ \theta = .226$; $\sin.\ \theta = .974$; this being the position of equilibrium attained by the rising dam, when backwater level is at F, we obtain

$$M_Z = 5.49\ Y^3 . w$$

$$M_x = 12.43\ Y^3 . w$$

If $\theta = 60°$; $\cos.\ \theta = \frac{1}{2}$; $\sin.\ \theta = \frac{\sqrt{3}}{2}$

$$M_Z = 4.54\ Y^3 . w$$

$$M_x = 9.90\ Y^3 . w$$

Examining the values of M_x and M_Z we find the former to be the greater for all values of θ; that is, the dam can be lowered when the backwater remains at the level of the junction between upper and lower gates.

c.—BACKWATER AT CREST OF GATE.

In this case both M_X and M_Z reduce to zero and the dam cannot be lowered unless it is heavier than water or unless the hydraulic chamber can be emptied to a level independent of the lower pool. In the latter case, if the outlet valves are suddenly opened there will be great probability of the dam overturning by θ becoming greater than 90°, and the volume of the hydraulic chamber thereby reduced.

For levels of backwater between F and the crest the moments M_X and M_Z will become smaller and approach equality as the level of backwater rises, but M_X is always the greater until the crest of the dam is reached.

MARSHALL'S BEAR-TRAP DAM, NO. 2.

MATHEMATICAL ANALYSIS.

By Henry Jervey, First Lieutenant, Corps of Engineers, U. S. A.

I.—GENERAL SOLUTION.

Referring to Fig. 9, Plate A, let DB represent the upstream leaf of the dam, FEG the hinged downstream leaf.

Assume DF and FE to be always equal and parallel to EG and GD respectively, making the right cross-section of the hydraulic chamber a parallelogram.

Denote distances and dimensions as follows, all expressed in feet:

$X =$ width of leaf DB.

$Z =$ width of leaf FE.

$Y =$ width of leaf $GE = FD$.

$h' =$ depth of center of X below surface of upperf pool.

$h'' =$ depth of junction of leaves below surface of upper pool.

$H =$ depth of foundation hinges below surface of upper pool.

$h =$ depth of backwater above foundation hinge when level of lower pool is at or below E.

$h''' =$ depth of E below surface of lower pool.

Let

$x =$ angle FDG expressed in degrees, minutes and seconds.

$w =$ weight of one cubic foot of water in pounds.

$P =$ water pressure due to h' on leaf X in pounds.

$2P_1 =$ water pressure due to h'' on leaf Z in pounds.

$P_2 =$ backwater pressure due to h on leaf Y in pounds.

Consider the dam to be one (1) foot long at crest, and the figure to represent a right cross-section: therefore, assuming surface of upper pool to be always level with the crest of the dam, we have

$P = X \cdot h' \cdot w$. pounds $= .5\, X^2 \cdot w \cdot \sin\alpha$ pounds. (1)

The center of pressure on X is at M, MD being $\frac{1}{3}\, X$, therefore the moment of P about D, tending to lower the dam, is

$P \cdot \overline{MO} = .167\, X^3 \cdot w \cdot \sin\alpha$ foot-pounds. (2)

Considering the interior of the hydraulic chamber, the surfaces FD and GE, being equal and under the same head of water, will be subjected to equal interior pressures; the moments of these pressures neutralize each other and there will remain only the upward pressure, $2P_1$, on Z tending to raise the dam $2P_1$ has equal components at E and F normal to X and Y; these may be considered as both acting at F, with lever arm $FD = Y$, to turn X about D.

From our notation we may write, Fig. 9, Plate A.

$2\, P_1 = Z \cdot h'' \cdot w$. pounds $= Z \cdot w \cdot (X - Y) \sin\alpha$ lbs. (3)

$\therefore 2\, P_1' = 2\, P_1 \cos\alpha = Z \cdot w\ (X - Y) \sin\alpha\ \cos\alpha$ pounds.

and

$2\, P_1' \cdot FD = Z \cdot Y \cdot w\, (X - Y) \sin\alpha\ \cos\alpha$ foot-pounds. (4)

For backwater pressure, level at or below E

$P_2 = .5\, h \cdot GK \cdot w$. lbs $= .5\, w \cdot \dfrac{h^2}{\sin\alpha}$ pounds (5)

and its moment about EG to raise the dam is

$P_2 \cdot \dfrac{\overline{KG}}{3} = .167\, w \cdot \dfrac{h^3}{\sin^2\alpha}$ foot-pounds. (6)

When backwater rises above E, the *additional* head h''' acts at centers of Y and Z and the center of pressure of that part of X between F and the surface of the lower pool. Since X and Y are parallel we may, without affecting resultant moment about D or G, consider Y extended to surface of water and pressed by back head of water $\underline{h + h'''}$ acting at $\frac{1}{3}$ the distance from G to surface of backwater.

Let P_4 = pressure in lbs on Z due to head h'''

Let P_3 = pressure in lbs on $Y + ET$ due to head h.

Let $h''' = m\,(X - Y) \sin\alpha$, m being any proper fraction $= \dfrac{FS}{FB}$

From the laws of pressure

$P_3 = .5\, [Y + m\ (X - Y)]^2\, w \cdot \sin\alpha = .5\ (h + h''')$
$(GE + ET)\, w \sin\alpha$ (7)

and its moment about G is

$P_3 \cdot \overline{NG} = .167\, [Y + m\, (X - Y)]^3\, w \cdot \sin\alpha$ foot-pounds (8)

tending to raise the dam.

$P_4 = Z \cdot m\, (X - Y) \sin\alpha \cdot w$ pounds. (9)

It may be considered acting at either E or F (EF being rigid) with its entire component,

$P_4 \cos \alpha$ perpendicular to X and Y and tending to lower the dam with its moment given by the equation

$$P_4 \cos \alpha \,.\, Y = Z \,.\, Y.\, m \,.\, w\,(X - Y) \sin \alpha \cos \alpha \text{ foot-pounds.} \quad (10)$$

The dam will take a position of equilibrium under any given conditions when the resultant of all the moments tending to raise the dam is equal to the resultant of all those tending to lower it.

Let us neglect in every case friction and effects due to currents, assuming, also, that the leaves of the dam are reduced to surfaces having neither weight nor volume:—

a.—WHEN THERE IS NO BACKWATER.

Equations (2) and (4) give the values of the opposing moments under this condition. Placing them equal to each other we obtain

$.167\, X^3\, w \,.\, \sin \alpha = Z \,.\, Y \,.\, w\,(X - Y) \sin \alpha \cos \alpha$ or by reduction

$$.167\, X^3 = Z \,.\, Y \,.\, (X - Y) \cos \alpha \quad (13)$$

an equation that must be satisfied when the dam reaches a position of equilibrium.

In equation (13) make $Y = .5X$, *i. e.*, suppose Z attached to the middle point of X, then we obtain

$$Z = .667 \frac{X}{\cos \alpha} \quad (14)$$

The dam is shown in this position of equilibrium in Fig. 10, Plate A, the shaded triangles here and elsewhere in Plate A representing half the resultant opposing moments.

In equation (14) if

$Z = X$, $\cos \alpha = .67$ and $\alpha = 48° \, 11'$

$Z = 1.333\, X$, $\cos \alpha = .50$ and $\alpha = 60° \, 00'$

From Fig. 9, Plate A

(14a) $H = X \sin \alpha =$ height of crest of dam.

Assume width of foundation to be equal to the width of the dam lying flat, *i. e.*,

$$Z + Y \text{ or (when } Y = \tfrac{1}{2} X) \; Z + .5\, X = .67 \frac{X}{\cos \alpha} + \frac{X}{2}.$$

Denote the ratio $\dfrac{\text{height of crest}}{\text{assumed width of foundation}}$ by F or

$$F = \frac{X \sin \alpha}{.667 \dfrac{X}{\cos \alpha} + .5X} = \frac{\sin \alpha \cos \alpha}{.667 + .5 \cos \alpha} \quad (15)$$

$$\frac{d\,F}{d\,\alpha} = \frac{6\,(4 \cos^2 \alpha - 4 \sin^2 \alpha + 3 \cos^3 \alpha)}{(4 + 3 \cos \alpha)^2}$$

F will be a maximum when $\dfrac{d\,F}{d\,\alpha} = 0$ or

placing $4 \cos^2 \alpha - 4 \sin^2 \alpha + 3 \cos^3 \alpha = 0$

we get $\cos \alpha = .635$ and $\alpha = 50° \, 30'$

corresponding to maximum value of F. Substituting this value of α in equations (14), (14a) and (15) we get

$$\text{For } \alpha = 50° 30' \quad \begin{cases} F = .498 \\ Z = 1.05\ X \\ H = .77\ X = .73\ Z \\ H = .30\ (X + Y + Z) \end{cases}$$

Assume width of foundation equal to $DG = Z$.
Let

$$N = \frac{\text{height of crest}}{DG} = \frac{X \sin \alpha}{\dfrac{\frac{2}{3} \cdot X}{\cos \alpha}} = 1.5 \sin \alpha \cos \alpha \qquad (16)$$

N is a maximum when

$$\frac{d\,N}{d\,\alpha} = 1.5\ (\cos^2 \alpha - \sin \alpha^2) = 0$$

or

$$\cos \alpha = \sin \alpha$$

or

$$\alpha = 45°$$

Substituting this value in equations (14), (14a) and (15)

$$\begin{matrix}\text{We get} \\ \text{for} \\ \alpha = 45°\end{matrix} \quad \begin{cases} N = .75 \\ Z = .943\ X \\ H = .707\ X = .75\ Z \\ H = .290\ (X + Y + Z) \end{cases}$$

The functions F and N are represented in Fig. 3, Plate B.

TABLE OF PROPORTIONS.

MARSHALL'S BEAR-TRAP DAM, No. 2, WHEN $Y = \frac{1}{2} X$, AND FOR NO BACK-WATER.

α	$\cos \alpha$	$\frac{X}{Z} = \frac{3}{2} \cos \alpha$	$\frac{Z}{X} = \frac{\frac{2}{3}}{\cos \alpha}$	$X + Y + Z = \frac{3}{2} X + Z$	$\frac{H}{X} = \sin \alpha$	$\frac{H}{Z} = \frac{\frac{3}{2} \cos \alpha}{\sin \alpha}$	$\frac{H}{X + Y + Z}$
30°	.866	1.299	.770	2.270 X	.500	.650	.220
35°	.819	1.229	.814	2.314 X	.574	.705	.248
40°	.766	1.149	.870	2.370 X	.643	.739	.271
45°	.707	1.0605	.943	2.443 X	.707	.750	.290
50°	.643	.965	1.037	2.537 X	.766	.739	.302
55°	.574	.861	1.161	2.661 X	.819	.705	.308
60°	.500	.750	1.333	2.833 X	.866	.650	.306
65°	.423	.633	1.576	3.076 X	.906	.608	.295
75°	.259	.389	2.574	4.074 X	.966	.376	.237

RATIO OF HEIGHT OF CREST TO TOTAL LEAF DEVELOPMENT.

Denote total length of leaves by $D = X + Y + Z$

when $Y = .5\ X$

$$D = 1.5\ X + Z$$

and

$$U = \frac{H}{D} = \frac{H}{1.5\ X + Z} = \frac{6 \sin \alpha \cos \alpha}{9 \cos \alpha + 4}$$

$$\therefore \frac{d\ U}{d\ \alpha} = \frac{6\ (9 \cos^3 \alpha + 8 \cos^2 \alpha - 4)}{(9 \cos \alpha + 4)^2}$$

U becomes a maximum when $\alpha = 56° \ 18'$.

b.—WHEN BACKWATER RISES TO E.

In this case the moment equation (2) is opposed by the moments in equations (4) and (6). Expressing this condition algebraically we have for equilibrium (position shown in Fig. 11, Plate A).

$$.167\ X^3 .\ w .\ \sin \alpha = Z .\ Y .\ w\ (X - Y) \sin \alpha \cos \alpha + .167\ w \frac{h^3}{\sin^2 \alpha} \quad (17)$$

In (17) let $Y = .5\ X$ and $h = Y \sin \alpha$. Hence by substitution and reduction we get

$$.167\ X^3 .\ w .\ \sin \alpha = Z .\ Y .\ w\ (X - Y) \sin \alpha \cos \alpha + .167\ Y^3 .\ w .\ \sin \alpha$$

or

$$.167\ X = .25\ Z \cos \alpha + .02083\ X$$

or

$$.1458\ X = .25\ Z \cos \alpha$$

or

$$Z = \frac{.5833\ X}{\cos \alpha} \quad (18)$$

and

$$\cos \alpha = \frac{.5833\ X}{Z} \quad (19)$$

$\therefore$ In equation (19) if $Z = X$; $\cos \alpha = .5833$; $\alpha = 54° \ 09'$

In equation (19) if $Z = 1.167\ X$; $\cos \alpha = .500$; $\alpha = 60° 00$

In the dam calculated to rise to 45° without backwater we have (*see table*)

$$Z = .943\ X. \quad \text{Therefore } \frac{X}{Z} = 1.0605$$

and when backwater rises to E

$$\frac{7}{12} \frac{X}{Z} = \cos \alpha = \frac{7.4235}{12} = .6186. \quad \text{Therefore } \alpha = 51° \ 47';$$

$$\sin \alpha = .7867$$

and

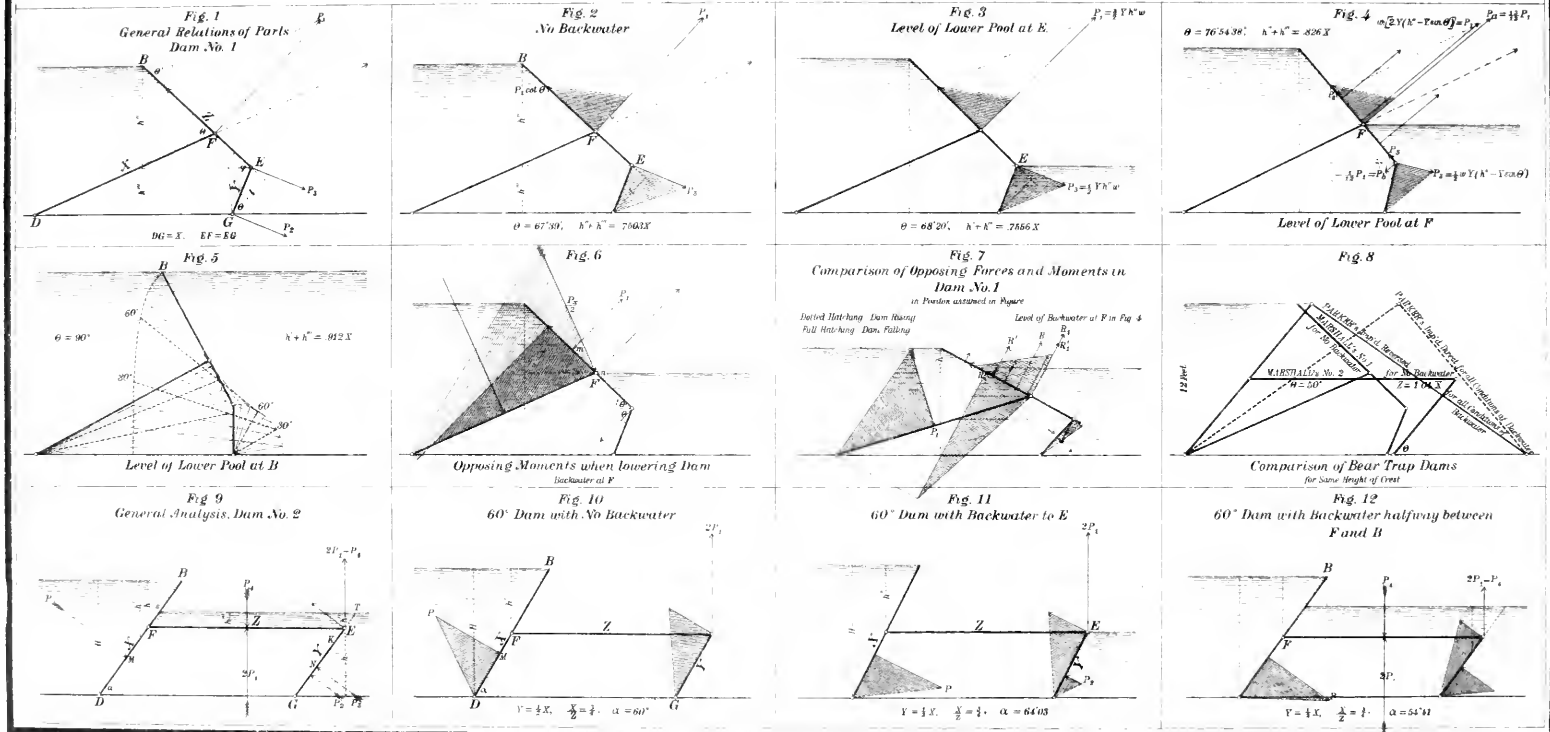
$$H = X \sin \alpha = .786\ X = .833\ Z.$$

In 60° dam

$$\frac{X}{Z} = .75; \cos \alpha = (.5833)\ (.75) = .4375; \alpha = 64° \ 03'$$

THE MARSHALL DAMS.

Plate A.



THE MARSHALL DAMS.

Plate B

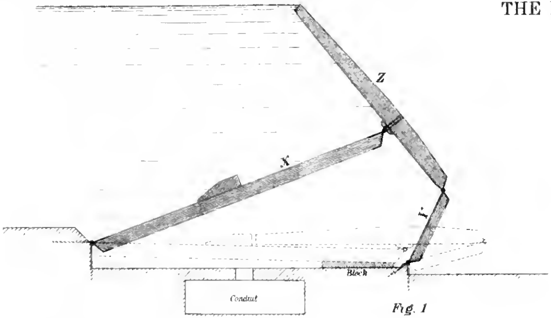


Fig. 1
Dam No. 1

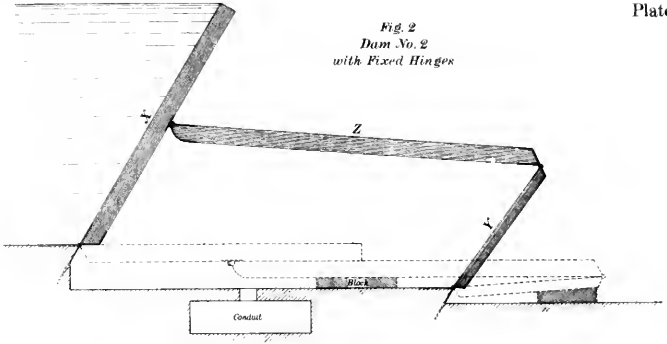


Fig. 2
Dam No. 2
with Fixed Hinges

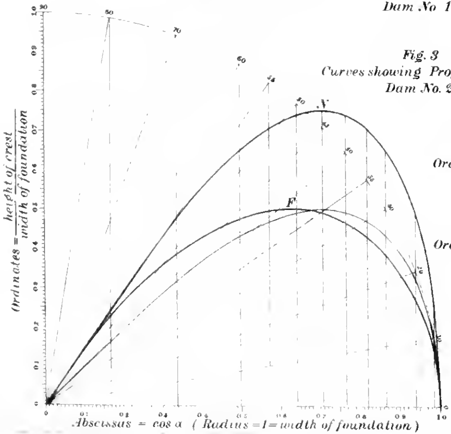


Fig. 3
Curves showing Proportions of
Dam No. 2

Ordinates of Curve $F = \dfrac{\text{height of crest}}{\text{width of foundation}}$, *when*

width of foundation $= Z + \frac{1}{2}X$

Ordinates of Curve $N = \dfrac{\text{height of crest}}{\text{width of foundation}}$, *when*

width of foundation $= Z$

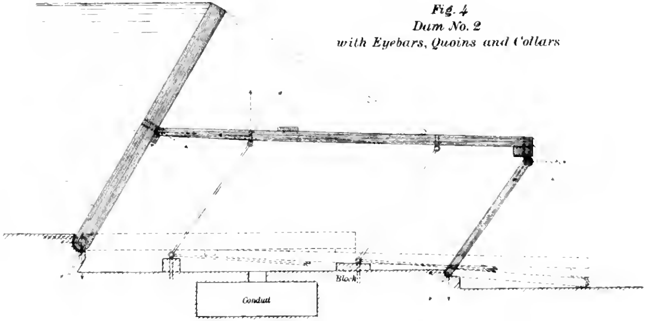


Fig. 4
Dam No. 2
with Eyebars, Quoins and Collars

c.—WHEN BACKWATER RISES ABOVE E.

(Position of equilibrium shown in Fig. 12, Pl. A.)

In this case the sum of the moments derived from P and P_4, equations (2) and (10) will be opposed by the sum of the moments derived from $2\,P_1$ and P_3, equations (4) and (8). Expressing this condition algebraically we must have for equilibrium

$$.167\,X^3\,.\,w\,.\,\sin x\;+\;Z\,.\,Y\,.\,m\,.\,w\,.\,(X - Y)\sin x\cos x$$
$$= \qquad (20)$$
$$Z\,.\,Y\,.\,w\,(X - Y)\sin x\cos x\;+\;.167\,[\,Y + m\,(X - Y)]^3 w\,.\,\sin x$$

Placing $Y = .5\,X$ and reducing we obtain, omitting factor $X^2\,.\,w\sin x$:

$$.167\,X + .25\,m\,.\,Z\,.\,\cos x = .25\,Z\cos x + .020833\,X\,(m+1)^3$$

or

$$\cos x = \frac{X}{Z}\left(\frac{8-(m+1)^3}{12\,(1-m)}\right) = \frac{X}{Z}\left(\frac{7+4\,m+m^2}{12}\right) \qquad (22)$$

If $m = O$ or backwater only as high as E, $\cos x = \frac{X}{Z}\,.\,\frac{7}{12}$, the same as in equation (19).

If $m = 1$ or backwater is level with the crest

$$\cos x = \frac{X}{Z}\,.\,\frac{12}{12} = \frac{X}{Z}$$

but making this supposition $m = 1$ in equation (20) we obtain an identical equation indicating the dam to be in a condition of indifferent equilibrium, *i.e.* $\frac{X}{Z}$ is a limiting value of $\cos x$ approached as the backwater gradually rises.

Between the limits $m = O$ and $m = 1$, $\cos x$ increases in value and is always positive.

For $\frac{X}{Z} = 1$:

$m = 0 \qquad \cos x = \frac{7}{12}$ and $x = 54^\circ\ 09'$

$m = 1 \qquad \cos x = 1$ and $x = 00^\circ\ 00'$

or the dam will rise to $54^\circ\ 09'$ when backwater level reaches E, Fig. 9, and on further rise of the backwater will lower gradually, reaching its flat position as the backwater level reaches the crest of the dam. This is true only under the supposition that the levels of the upper and lower pools follow the dam in all its positions, that no water pours over the crest, and that there is perfectly free communication between the upper pool and the hydraulic chamber. In an actual dam the crest would lower only until submerged by the backwater, the lowering would be assisted by the current and water from the upper pool, and resisted by the forces opposing the movement of the water out of the hydraulic chamber.

In equation (22) for $\frac{X}{Z} > 1$ the highest position of dam will be less than 54° 09′, and it will, under conditions stated above, fall flat before $m = 1$, or before backwater reaches the crest.

If in equation (22) $\frac{X}{Z} < 1$ the highest position of the dam will be at an angle, whose cosine is less than $\frac{7}{12}$, *i. e.*, $\alpha > 54° 09′$, and the dam will not fall flat when backwater reaches the crest, but will attain its state of indifferent equilibrium at some angle whose cosine is less than 1, its value depending on the ratio, $\frac{X}{Z}$

Consider the dam proportioned to rise 60° with no backwater; in this $Z = \frac{4}{3} X$, or $\frac{X}{Z} = \frac{3}{4}$ and $\cos \alpha$ (for no backwater) $= .5$;

$$\text{Therefore } \alpha = 60°$$

For backwater as high as E, Fig. 9, Plate A, $m = 0$ in equation (22), and

	$\cos \alpha = \frac{3}{4} \cdot \frac{7}{12} = \frac{7}{16}$	$\therefore \alpha = 64° 03′$
If $m = \frac{1}{10}$	$\cos \alpha = \frac{3}{4}\ (.6175) = .4647$	$\therefore \alpha = 62° 19′$
If $m = \frac{2}{10}$	$\cos \alpha = \frac{3}{4}\ (.6533) = .4900$	$\therefore \alpha = 60° 39′$
If $m = \frac{3}{10}$	$\cos \alpha = \frac{3}{4}\ (.6908) = .5181$	$\therefore \alpha = 58° 48′$
If $m = \frac{5}{10}$	$\cos \alpha = \frac{3}{4}\ (.7708) = .5781$	$\therefore \alpha = 54° 41′$
If $m = 1.0$	$\cos \alpha = .7500$	$\therefore \alpha = 41° 25′$

CASE II.—DAM FALLING.

Hydraulic chamber in communication with lower pool only.

In this case it is evident that the resultant of all the forces acts to depress the dam until the crest is submerged, after which the weight of the dam alone must be relied upon in still water for further lowering. A mathematical discussion is unnecessary,

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V. Bear-Trap Weirs.

By W. A. Jones, Lieut. Colonel, Corps of Engineers, U. S. A.

The new form of bear-trap weir is a very interesting addition to the repertoire of the engineering profession. It unfolds wide vistas before us. I will here touch upon one or two. At Sandy Lake dam, Minnesota, the United States government has made an application of it as a lock gate, the first of its kind, I believe. The lock has been completed since the fall of 1895. The gates operate freely under a head of between one and two inches. This easy action seems to settle the question of the adaptability of this form of weir to this purpose. Except under the re-

versed conditions, no auxiliary raising power is needed. The upper gate can be raised, when a boat is in the lock, going down, by lowering the lower gate a little, just enough to create a current over the upper. There is no lift wall. I think it may be safely announced that the bear-trap weir is available as a lock gate in many instances, particularly for gates to be operated under reversed head. For high lifts, a secondary set of anchor chains along the line of center of pressure will avoid cumbersome construction. For narrow locks with high lifts there may be cases where this form will take up too much of the length of the lock. It is of simple construction and design, easy of operation, puts no strain on side walls, requires no machinery, and is accessible for repairs in the ordinary way. It will ordinarily keep itself clear of sediment, and in extreme cases the feed and exhaust water can be specially handled so as to create a swirl which will keep it clear. It furnishes a reversible gate to enable tide locks to be operated at all stages of tide.

The gates at Sandy Lake dam have since been operated every day except two, during the whole of a Minnesota winter. It has been a mild winter, on the whole, with spells of extreme severity. They have been operated at temperatures below 30°F. without the aid of steam. At very low temperatures ice will form inside along the contact of gate and wall. A light, portable steam boiler furnishing steam through a hose and small nozzle removes it quickly, and is useful in clearing ice from any sort of gate which has to be manipulated in winter. This feature will enable locks to be operated in any low temperature likely to occur in places where canals are used. It will make it possible to extend the period of navigation several days for all canals subject to winter closing. And for some short canals there seems to be a reasonable certainty of keeping them open for navigation all winter. By keeping a current running through, there can be maintained a channel of open, or thinly iced, water through which boats could pass, while the locks can be kept open by operating the gates. With the facts now before us, it certainly looks as though the navigation of the Great Lakes might be made continuous. The principal difficulty would probably be found in Detroit River. But there is such a great volume of water flowing through that the concentration of velocity in an open or thinly iced channel would probably prevent the formation of very thick ice.

Again, this form of weir enables the control of the level of ponded water. Now it is a far cry from a mill pond to the great inland seas of America, and yet the time has come for consideration of the question whether their broad surfaces may not be placed at a desired level and the same maintained, independent of climatic conditions, by the use of great dams discharging over the new bear-trap weir.

The discussion of Mr. Powell's paper seems to have developed into a symposium on

and it has fallen to my lot to present the bear-trap forms designed by Mr. Lang and myself. It has seemed to me that a great step forward was taken when Mr. Lang detached the intermediate leaf of the Parker form and substituted chains for the anchorage. This abolished the friction of two hinged joints acting under a forced parallelism with the two floor joints, and relieved the system of a lot of adverse pressures by folding the intermediate leaf outside of the hydraulic chamber instead of inside. The evolution of the present form seems to have been:

I.

Two leaves folding down, one upon the other, free at upper ends.

II.

Connecting the two leaves of (I) with an intermediate leaf, folding *into* the hydraulic chamber.

III.

Detaching the lower joint of the intermediate leaf of (II) and allowing it to fold down *outside* the hydraulic chamber by sliding upon the upper leaf, and connecting the crests of the upper and lower leaves by chains. Other forms have been designed, but I am not yet satisfied they have developed any marked advance on these three.

By the term "Bear trap weir" is meant a rising and falling weir formed of two or more leaves joined together and to the floor of the waterway, the said leaves being raised by introducing water beneath them from the upper pool, and lowered by exhausting said water into the lower pool.

The Lang form is III, as above. The downstream leaf is called the "lower" leaf. The upstream leaf, the upper, and the intermediate leaf, the "idler." The feed and exhaust of water through the hydraulic chamber formed by the leaves and waterway walls may be through the floor or side walls. The manipulation of the weir (I will use the term "gate" hereafter) is simplified by the use of one valve. I have designed a cylinder valve which enables the operation of the gate by one motion of the operator. It is an application of the 3-way cock. By setting the valve so that the water which runs into the hydraulic chamber equals that which runs out, the gate will stand indefinitely at any desired height. Two positions of the valve effect this. One, which makes the opening of the outlet port equal that of the inlet port, varied by the effect of leakage. The other where the outlet valve is wholly closed, or closed so as to offset the leakage, and hold a fixed quantity of water in the chamber. In the later case there is no waste of water, except leakage. Plain slide valves

can often be used. Where they carry much pressure they should be on roller bearings of gun metal. The cylinder valve can be balanced so as to be of easy manipulation under great pressures.

Mr. Lang has designed sliding props to hold the gate in the up position for repairs. Where there is no backwater the gate can be emptied easily. In all important structures, provision should be made for temporary coffer-dams above and below, to be used when repairs are necessary. These can be simple and inexpensive.

There are now completed and in successful operation gates of this form at the following places:

SAINT CROIX RIVER, AT NEVERS, WISCONSIN.

1 gate, 80′ length of crest, 16′ rise.
1 " 24′ " " " 16′ "
1 " 20′ " " " 16′ "

Completed in winter of 1890–91.

MISSISSIPPI RIVER, AT LITTLE FALLS, MINNESOTA.

1 gate, 60′ length of crest, 7′ rise.

Completed in winter of 1891–2.

CHIPPEWA RIVER, AT LITTLE FALLS, MINNESOTA.

1 gate, 58′ length of crest, 12′ rise.
1 " 14′ " " " 12′ "

Built in 1892–3.

CHIPPEWA RIVER, AT CHIPPEWA FALLS, WISCONSIN.

1 gate, 80′ length of crest, 6′ rise.

Built in 1893–4.

SANDY LAKE DAM, MINNESOTA, U. S. GOVERNMENT.

1 gate, 11′ length of crest, 12′ rise.
2 " 40′ " " " 13′ "

Through a misapprehension of my instructions, the upper leaves of the Sandy Lake lock gates were made lighter than water. This will cause them to fail at some stages, but the difficulty will be remedied at a convenient time. Three more are in course of construction on the Mississippi River at Minneapolis, Minn., in the new power dam of the Minneapolis Mill Company. They are 50′ length of crest and 16′ rise.

In comparing different forms, let the lengths and relations of the leaves be properly adjusted to cover the same conditions. Then, in each case, make a discussion of the values of the operative pressures under the conditions of head, varying or otherwise, and for a number of positions between the up and down limits. Note the relation between the

available and the useful pressures and how much of the former is non-effective. Note particularly the values of the useful pressures at the positions of minimum effect. In the Parker form this position is reached gradually in the final stages of depression, where a sort of dead point is reached which allows a very appreciable movement to take place without any corresponding lowering of the gate. In the Lang form it is approached gradually in lowering from the full raised position to that where the angle between the idler and lower leaf becomes a minimum. Here the friction at the toe of the idler may become sufficient to lock the movement, unless the parts are properly adjusted.

The inherent virtue of this system of weir is that it will carry a great head, and lower, under simple and easy control, *against all of that head.* It may be described as a device which enables a leaf to be rotated upwards on a floor axis by means of the pressure from the head, and, at the same time, to enable that leaf to be lowered *by the pressures from the same head.* It is possible, at all times, to release all upward pressures from the lower leaf, leaving nothing acting on the gate excepting the downward hydraulic pressures increased by its Sp. G. in excess of that of water. For operation under delicate shades of pressure friction becomes a principal item, and the less the number of joints where friction may arise the better.

The making of wet operative models will be attended with difficulty unless the parts are of metal and glass. They are apt to fail from causes not effective on a full-sized structure. Leakage and friction become factors wholly out of proportion to what they actually are in practice.

ANALYSIS OF THE PRESSURES.

Let x represent the length, bd, of the upstream leaf (Plate I, Fig. 1), y that of ac, the downstream leaf, $y - x = ad$, the chain connection. Let ae be the idler. Sp. G. of the moving parts in water $= 1.0$. Friction $= 0$. Head $= h''$, under the assumption that it is concentrated at a by a stop plank. Let the hydraulic chamber be connected with the upper pool and cut off from the lower. All pressures to the left of a being balanced, as also those on bd to the right of a, it is evident that any positive value for h'' will create an operative upward pressure. The full effect of the pressure from h'' will act from a to c on ac. As this is the position of minimum effect of the raising forces, no further consideration is necessary. Conversely, connect the hydraulic chamber with lower and cut off the upper pool and the pressure from h'' will act with great efficiency in holding the gate down. Practically, a very small head will operate the gate. The joints at a and d being relieved from any necessity for moving parallel to each other and to those at b and c, the friction from these sources will be small.

BEARTRAP WEIRS

(JONES.)

PLATE 1.

Fig. 1

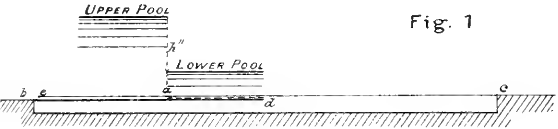


Fig. 2

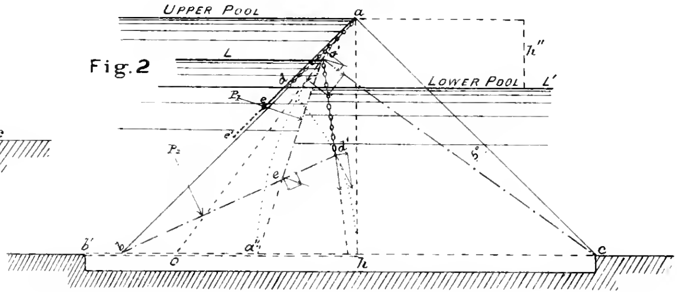


Fig. 3

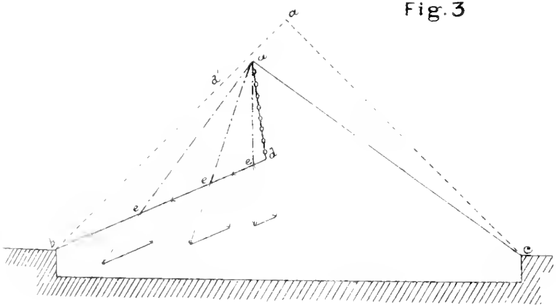
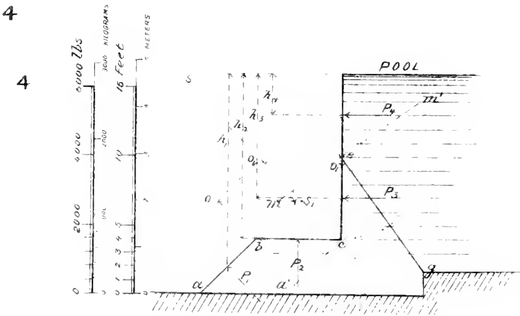


Fig. 4



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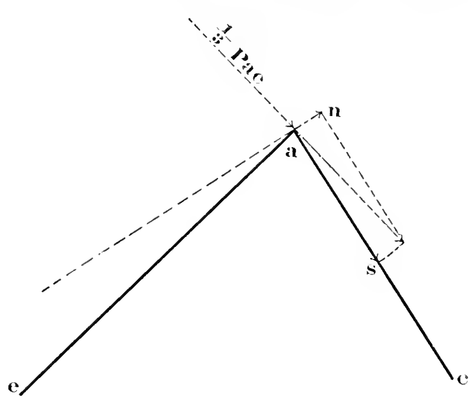
Let Fig. 2, Plate I be the up position of the gate. Assume *ac* standing at an angle of 45° with *bc* and *ab* at right angles with it.

$$ad = y - x$$
$$de = z$$
$$ae = y - x + z$$

In this position, with hydraulic chamber connected with upper and cut off from lower pool, there is no unbalanced pressure on *ae* and *be*. That from h'' is wholly on *ac*, and so long as its moment is sufficient to equal or exceed that of the effective weight of all the moving parts the gate will stay up. As before, a very small head will suffice. Now change the valves so that hydraulic chamber is connected with lower and cut off from upper pool. The water in it will run out until its level is same as that of lower pool. This releases *ac* from all pressures which held it up and brings into play the whole weight of the structure above the level of lower pool. The whole pressure from h'' is transferred from the under side of *ac* to the upper side of *aeb*. It tends to rotate *ae* downward about *a*, and *bd* downward about *b*. Everything tends to move the system downwards except the pressures carried at *a* and *b*, and the friction at *e*. Any difference of level between upper and lower pools will create relatively the same effects.

By the term "critical" position is simply meant that position where the downward tending forces are a minimum. By gradually lowering the gate it will be seen that the angle at *a*, between *ae* and *ac*, gradually decreases until a minimum is reached at about 5° of depression of *ac*, and thereafter increases to 180°, nearly, as the gate descends. Fig. 2, Plate 1, shows this position. Whatever water flows over the crest while lowering adds its dynamic effect on the lower leaf to the downward forces. We will assume none passing. In this position we will have on *ac* and *aeb* the same conditions as before, except that that portion of the pressure on *ae*, which is carried at *a*, is decomposed thus:



One component, *as*, goes down *ac* with no moment. The other, *an*, acts tending to rotate *ac* upward against the downward tending forces brought to the same point of application by the chain *ad*. In case the conditions render it necessary, *an* can be abolished as an opposing force by slightly increasing the length of *bd* and *ae*.

One part of the down pressure on idler and upper leaf is transferred after decomposition, to *a* along the line *ad*. Fig. 3, Plate I. Here it is resolved again, the normal, or moment component, tending to rotate the lower leaf. This component is decomposed, one part going down *ae* to *e*. Here it becomes decomposed, the normal component creating friction and tending to rotate the upper leaf, the other tending to slide the point of *ae* along the surface of the upper leaf. In Fig. 3 I have shown three positions of *ae*, corresponding to different values of the angle *eac*, two less than 90°. Resolving the force at *e*, it will be seen how the sliding component decreases and the friction component increases as the angle *eac* decreases. The friction component is practically rendered ineffective by introducing rollers at *e*.

As the angle at *a* decreases, the sliding component at *e* decreases until it equals the friction created by the friction component. At this point, the toe of the idler being unable to slide, the downward movement will cease. When *ae* is at right angles with *bd* the sliding component becomes 0. By giving *ae* such length as to make it meet *bd* at 45° the two components become equal. Now if we remove most of the friction by making it rolling, it will be evident that the point *e* will freely slide. By constructing the opposing forces at *a* under this assumption, it will be seen that there is a sufficient preponderance of downward pressure. Hence this may safely be assumed as giving a minimum value for the angle *eac*.

A general analysis of the relations between the pressures and lengths of the moving parts involves many elements, and will be complicated. I will only attempt one, based on certain assumptions which are either correct or nearly so. Let *ac*, Fig. 2, Plate I, be the lower leaf, standing on an angle of 45° with the horizontal; *ab*, the upper leaf and chain at right angles. Let $Ca'd'b$ be the most unfavorable position in descending. Take it so that $a'd'$ prolonged passes through h, the middle of bc. Assume $a'e$ on the chord $a'a''$, also ac as unity. $oa' = \tan oca'$, oc sec. $oh = oc - \frac{1}{2}\, bc$, $\angle a'o\,c = 90° - \angle oa'c$, $bd = bh$, $de = ab - bd$, $\angle oa'a''$ is known. From $a'o$, oh, and included angle deduce $\angle oa'\,h$ $\angle ea'd' = \angle oa'h - \angle oa'a''$. From ea', $a'd'$ and included angle, get ed'. Hence be,

Let $\angle ea'd' = \theta$

and $\angle ea'c = \theta'$

$\theta' = \theta + \angle da'c$

The critical conditions will be for small values of h'', the head, or difference of level. For such the pressure on $ea' = P_{,} = ea' \times h'' w$, w being the weight of a cubic unit of water. Its moment component around b will be transferred to d', and its component along the chain $d'a'$ will be

$$P' f(\theta)$$

Similarly, the component from be which acts along $d'a'$ will be

$$P'' f(\theta)$$

Let $P' + P'' = P_d$

The moment component around c applied by the chain at a' will be

$$P_d f(\theta)$$

One third the pressure on ea' is carried at a'. When $\theta + < d'a'c = 90°$, it will have no moment about c. When it is greater than 90° the moment component will be added to $P_d f(\theta)$. When the angle is less than 90°, the moment component will be applied at the same point but will act in opposite direction. It will be

$$\tfrac{1}{3} P_{,} f(\theta)$$

Equate the values of these opposing forces, using θ as the unknown quantity. Substitute $\theta' - < d'a'c$ for θ and solve for a minimum value of θ' by differentiation. The corresponding value of ea' will result.

TO DESIGN THE STRUCTURE.

The reference of the floor of the waterway and that of the surface of the upper pool will be known Fig. 2, Plate I. Let bc be the floor and ah the height of the upper pool. From a draw ab and ac at right angles, ac will be the lower leaf in position and length. ab, the upper leaf and chain connection in preliminary position and length. From b as center draw arc with radius bh to cut ab in d. d is the link point for bd and ad to fold upon. bd will be the upper leaf and ad its connection with lower leaf. An angle of 45° may not be the best for lower leaf to stand upon, but it is found in practice to be very near it, and it is adopted for the sake of simplicity. It will be observed the $< cac$ is a right angle. For the first 5° of descent this angle decreases to a minimum and thereafter increases through the whole descent. The broken lines show, diagrammatically, the structure in this position. Assume $a'c$ on the cord $a'a''$ as the length of the idler. This will be sufficient in most cases. To give upper leaf and idler such length as will make the angle at $a' = 90°$ very nearly, and abolish the adverse component at a': Rotate the system to the down position as shown. Move b to the left a distance equal to $\frac{1}{10}$ ac. Make the idler $= a'b'$. This completes the design so far as position and lengths of the moving parts are concerned. c and b

are the axes of the floor hinges. The angle *eac*, between lower leaf and idler, will not become less than 90° in the movement of the gate, and all the unbalanced forces will act positively in raising or lowering the gate.

PRACTICAL CONSIDERATION.

I will indicate some practical points developed by our experience:

No grating will keep a certain amount of finely divided floating matter from getting into the hydraulic chamber. If the floor hinge joints are on the upper corner of the leaves, an angle will result between the leaves and floor walls and this floating stuff may gradually get so packed in it as to prevent leaves from going clear down.

Ports and flumes should be of ample size.

Iron work should be protected from the oxidizing action of water. Moisture seems to be a necessary adjunct of oxidation of iron at ordinary temperatures. There is more or less oxygen, possibly in dilute form, in water, and hence iron rapidly oxidizes in it. The use of copper or zinc plating or paraffin paint is suggested. Coating by dipping in a melted alloy of zinc and tin and bismuth is also suggested. Friction rollers, particularly.

In wooden gates, to counteract the effect of swelling, they should be nearly constructed, and then allowed to thoroughly soak before final parts are added.

Reciprocating valves are not necessary, except, a single valve is quicker and simpler in operation.

To control excessive pressures at any point of a controlled opening, use small "bleeder" valves.

To keep hydraulic chamber reasonably free from sediment, adjust inlet and outlet ports so as to create a swirl in it.

To keep valves and chamber free from ice, leave valves open slightly so as to keep up a motion of the water. In case ice forms on contact between leaves and walls, remove it with a steam jet.

The joints between ends of leaves and the side walls need not be tight in most cases. A play of one inch can be freely allowed where leakage is not of consequence. In the up position, leakage can be pretty well stopped by letting the lower leaf rest against stops on the side walls. If it is desired to pack the joints in all operative positions, a wedge-shaped strip, pressed into the joint by springs, will do it. Rubber flaps and tubes are found inoperative. They create too much friction.

REVERSIBLE WEIR WITH SHORT BASE.

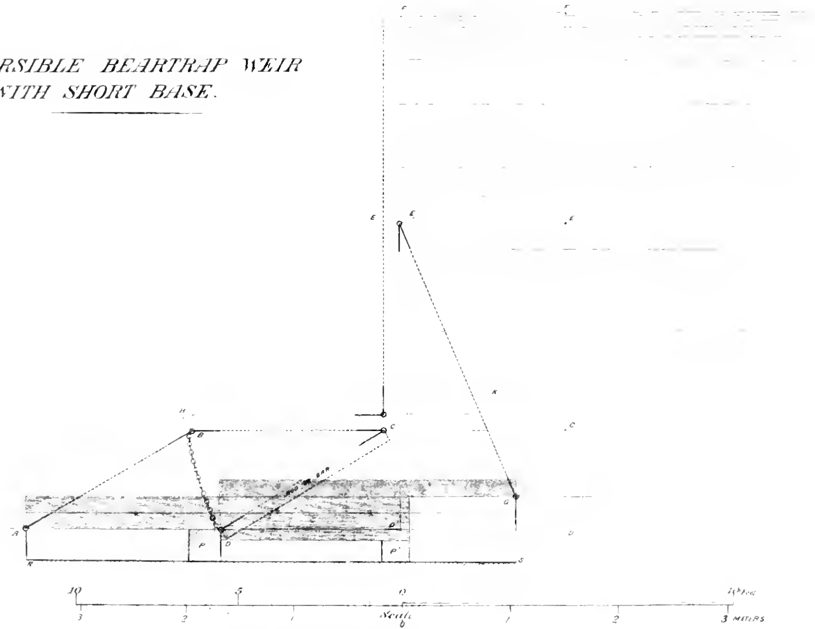
There will be cases where the length of the floor of the waterway occupied by the gate must be as small as possible. The form shown in Plate II is designed to meet them. The link members fold backwards

BEARTRAP WEIRS.

(JONES.)

PLATE II.

REVERSIBLE BEARTRAP WEIR WITH SHORT BASE.



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towards the upper floor hinge and are braced by the chain and rod connections BD and CD. In cases where the overfall is great and HC is left exposed, or where floating matter passes over the crest, a fender can be placed at EH. On account of the moments of forces on CF around E acting in opposition the gate will reach its full height without shock. Theoretically, EF can be made longer than as shown. In the raised position the system is perfectly rigid and strong. Any difference of level will lower it. Assuming the submerged Sp. G. $= 1.0$ a head sufficient to create pressures in excess of the friction, and weight of exposed parts will raise it. Any attempt at establishing a general relation between the lengths of the section parts by analysis will be unsatisfactory and result in an approximation which can be reached some other way, unless the dynamic effect of the water passing over the crest F is taken into consideration. This will introduce serious complications in the analysis. These remarks apply to any form of bear-trap. The rod CD is introduced to complete the link $AHCD$. The chain BD locks the system. P and P' are pillow blocks.

The following procedure is recommended for designing this form. Let AD' be the floor of the waterway and $H = F'D'$ the height of the pond upon it. $C'D'$ must be assumed. Moving C' downwards will reduce the base RS, in its ratio to H. Moving it upwards will increase it. Local conditions will largely affect the assumption. It will be an advantage to hold BC beneath the level of the lower pool. Having $C'D'$, $E'C'$ may ordinarily be assumed equal to $E'F'$. Now draw FE CD' vertical. Make $CD' = C'D'$ and $CE = EF$. Draw BC horizontal $= CE$. Draw AB and CD parallel and to the floor so that B will rotate down to D. Describe an arc to the floor, from D with radius CD. Describe ark CK from E. Now determine the thickness of the members AB, BC, and CF from a consideration of the strains to which they will be subjected. Make them of equal thickness for simplicity. Twice that thickness above AD' draw GG' parallel to it. On this line find the point G equidistant from the arcs drawn from E and D as centers. Draw GE and give this member same thickness as the others, for simplicity. Draw in the other members, showing thickness and articulate with hinge joints as shown. This articulation is now such as will fold down neatly. In this down position, when pressure is introduced in the hydraulic chamber, that which comes upon the upper side of CE will just about balance that which comes upon the under side of BC and that upon AB is the active force in raising the gate. As the gate raises, the pressure on EC becomes less in proportion to that which comes on BC and the lifting effect increases but is gradually offset by the pressure on EF, thus relieving the shock. Let us compare the forces with the assumed proportions. See Fig. 4, Plate I. All lines to scale, no backwater.

$h_1 = 14'$, $h_2 = 12'$, $h_3 = 9'$, $h_4 = 3'$
$ab = 5'.5$, $bc = ce = ef = b'$

$$P_1 = ab \times h_1 w = 4812.5 \text{ lbs.}$$
$$P_2 = bc \times h_2 w = 4500 \text{ “}$$
$$P_3 = ce \times h_3 w = 3375 \text{ “}$$
$$P_4 = ef \times h_4 w = 1125 \text{ “}$$

The strains concentrated at c are assembled graphically upon cs. Their moment effect, em', around g as a center, will be opposed by em, that of $P_4 + \frac{1}{3}P_3$, $em = 2250$ lbs., $cm' = 2800$ lbs.

Let $x = ab$, $y = bc = ce = ef$, $\theta = \angle baa' = 45°$, $\theta' = \angle gec$.

Normal pressure at b from $ab = bo = \frac{1}{3}h_1 wx$
“ “ “ b “ $bc = bo_1 = \frac{1}{2}h_2 wy$
“ “ “ c “ $bc = bo_1 = \frac{1}{2}h_2 wy$
“ “ “ c “ $ce = co_3 = \frac{2}{3}h_3 wy$
“ “ “ e “ $fec = eo_4 = \frac{1}{3}h_3 wy + h_4 wy$

Take the moment around a. The rotating component of P_2 at b is:

$$\tfrac{1}{2}P_2 \cos\theta = \tfrac{1}{2}h_2 wy \cos\theta$$

Add this to $\frac{1}{3}P_1$ for the whole rotating force:

$$\tfrac{1}{3}h_1 wx + \tfrac{1}{2}h_2 wy \cos\theta = \tfrac{1}{3}h_1 wx + 2h_4 wy \cos\theta$$

The rotating force at c is:

$$4\, h_4 wy \cos\theta$$
$$cs = \tfrac{1}{3}\, h_1 wx + 6\, h_1 wy \cos\theta$$

Its component along $c\,f$ is:

$$\frac{\frac{1}{3}\, h_1 wx + 6\, h_4 wy \cos\theta}{\cos\theta} = \frac{h_1 wx}{3\cos\theta} + 6\, h_4 w\, y$$

Decompose at e for the moment component around g, which is:

$$em' = \left(\frac{h_1 wx}{3\cos\theta} + 6\, h_4 wy\right)\sin\theta' \qquad (1)$$

The moment component of the opposing force is:

$$em = 2h_4 wy \cos\theta' \qquad (2)$$

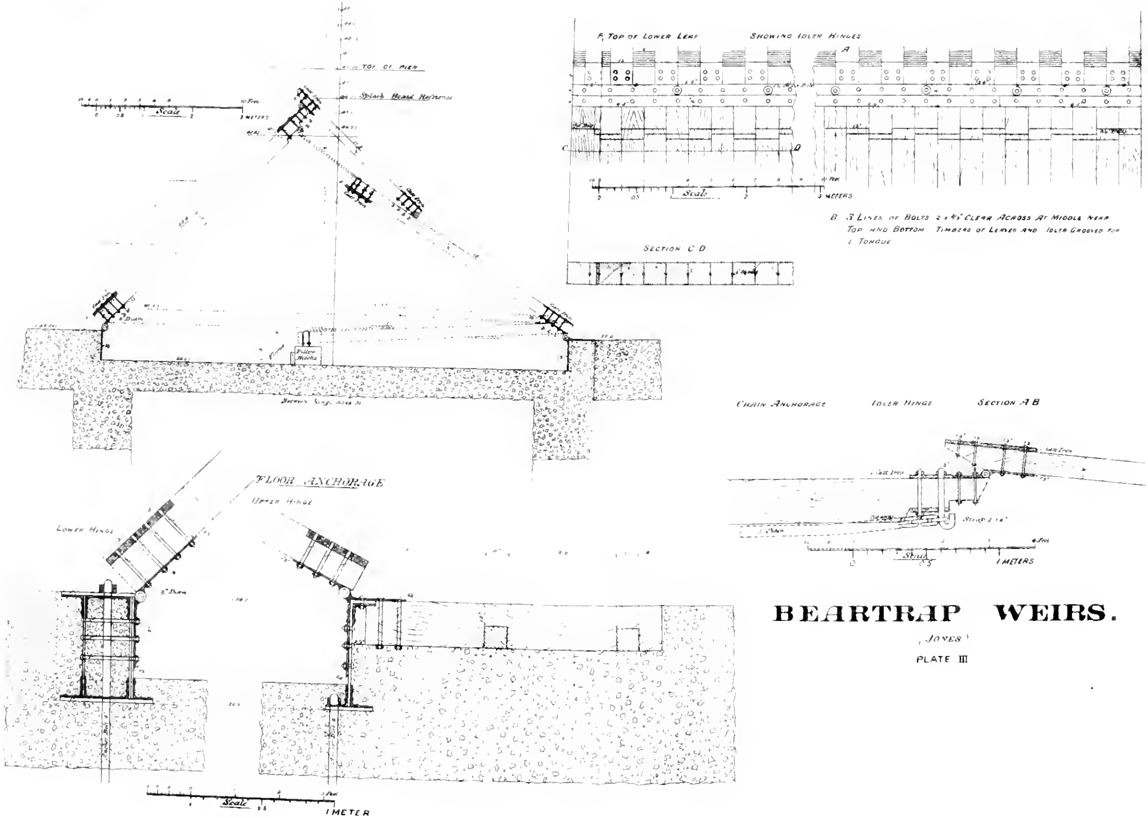
Equate (1) and (2):

$$\frac{h_1 \tan\theta'}{3\cos\theta}\, x + \left(6h_4 \tan\theta' - 2\, h_4\right) y = 0 \qquad (3)$$

As this discussion ignores the acting weight of the moving parts, and the dynamic and static effects of the water falling over the crest, it is not considered satisfactory.

A LONG WEIR.

As a summing up of the experience so far gained I present on Plate III, a design for a bear-trap weir 600′ long with a rise of 16′. To



BEARTRAP WEIRS.

(JONES)

PLATE III

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adjust the effects of undue pressures concentrated at points along the crest, small "bleeder" valves, controlled by the operator observing buoys along the crest, are introduced so as to connect the hydraulic chamber with the lower pool. No attempt is made to stiffen the structure along its length. Let it warp, it will operate just the same, in my judgment. The case is assumed where the river bed is full of boulders down to bedrock, so that piles can not be used in the foundation. The anchorage is effected by a combination of built beams and concrete beams or cores. I would coffer-dam small sections consecutively, such as could be conveniently pumped out.

NOTE.—Since writing the above, the gates at Sandy Lake Dam have failed to operate well, owing to conditions that will not be apparent until after an examination, which will be made as soon as possible.

VI. MODIFIED DRUM WEIR.

BY H. M. CHITTENDEN, CAPTAIN, CORPS OF ENGINEERS.

MR. POWELL'S paper is a timely contribution to the literature of movable gates. The subject has of late attracted so much attention that a complete historical review and a summary of existing knowledge pertaining to it, such as are here given, are at this time particularly valuable.

In discussing this paper I shall confine myself mainly to a consideration of the modified drum weir which Mr. Powell has assigned me the credit of proposing.

The principal difficulties which confront the inventor in dealing with any of the "bear-trap" forms of movable gate are:

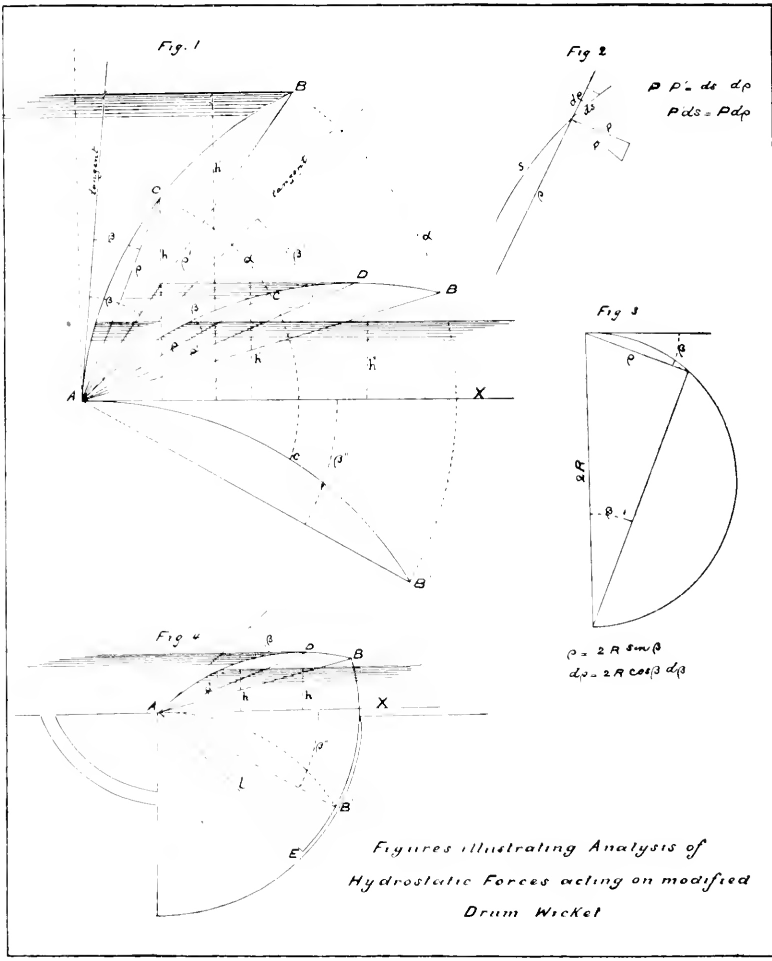
(1) The necessity of having several parallel axes of motion (from two to five) of lengths equal to the width of the sluice which the gate is to close. The mechanical difficulties of constructing and adjusting these hinges so that they may work freely and prevent leakage, are great.

(2) The necessity of having one or more angles either on the upstream or downstream side of the gate in which the lodgment of drift is liable to occur and prevent the complete lowering of the gate. This compels a resort to auxiliary leaves, called idlers, which serve no other purpose than to fend off drift, but which increase the cost, and complicate the operation, of the gate.

(3) The great difficulty of building and operating a long gate in sections, and the consequent necessity of building it all in one piece. The changing positions of the leaves with reference to each other, as the gate

is raised or lowered, make it difficult, if not impossible, to close the ends, so as effectually to separate the chambers, if the gate were built in sections.

(4) Other drawbacks of a less serious nature may be mentioned; such as the sliding surfaces in some forms, which introduce the uncertain element of friction; and the impossibility of intermediate bracing to sup-



Figures illustrating Analysis of Hydrostatic Forces acting on modified Drum Wicket

port pressure surfaces, thus necessitating a heavier and more costly construction.

The proposed modification of the drum weir is free from most of these defects:

(1) It has but one axis of motion and but one hinge.

(2) It has no angles in which drift can lodge, and it therefore requires no idlers.

(3) It can easily be built in sections, since the two pressure surfaces are always in fixed relative positions to each other, and the ends of the gate can therefore be closed.

(4) There are no sliding surfaces, and the two leaves can be made to support each other by proper bracing, thus reducing the weight of the structure to a minimum.

It is urged against this form of gate that the cost of the chamber will be a great drawback. In some sites this would be the case; but in many it would not; as for example where it is proposed to use the gate simply to increase temporarily the height of a fixed weir. The drawings (Figs. 6 and 7) illustrate a case where it is designed to have a movable dam upon a fixed weir, to be kept up in ordinary stages, but to be lowered during flood flow to the crest of the weir. In such a case, if the drum weir were adopted, the chamber would become a part of the fixed weir and would not greatly increase its cost.

It is clear also that the accumulation of silt, sand or gravel in the chamber could be entirely prevented by an arrangement of discharge and inlet pipes, such as is shown in the drawings; for such an accumulation would gravitate to the bottom of the chamber where it could be flushed out without difficulty.

The strong jet which would always issue from whatever space might exist between the cylindrical surface of the gate and the upper edge of the downstream chamber wall would effectually prevent the access of gravel or sticks into such space and the consequent liability to wedging.

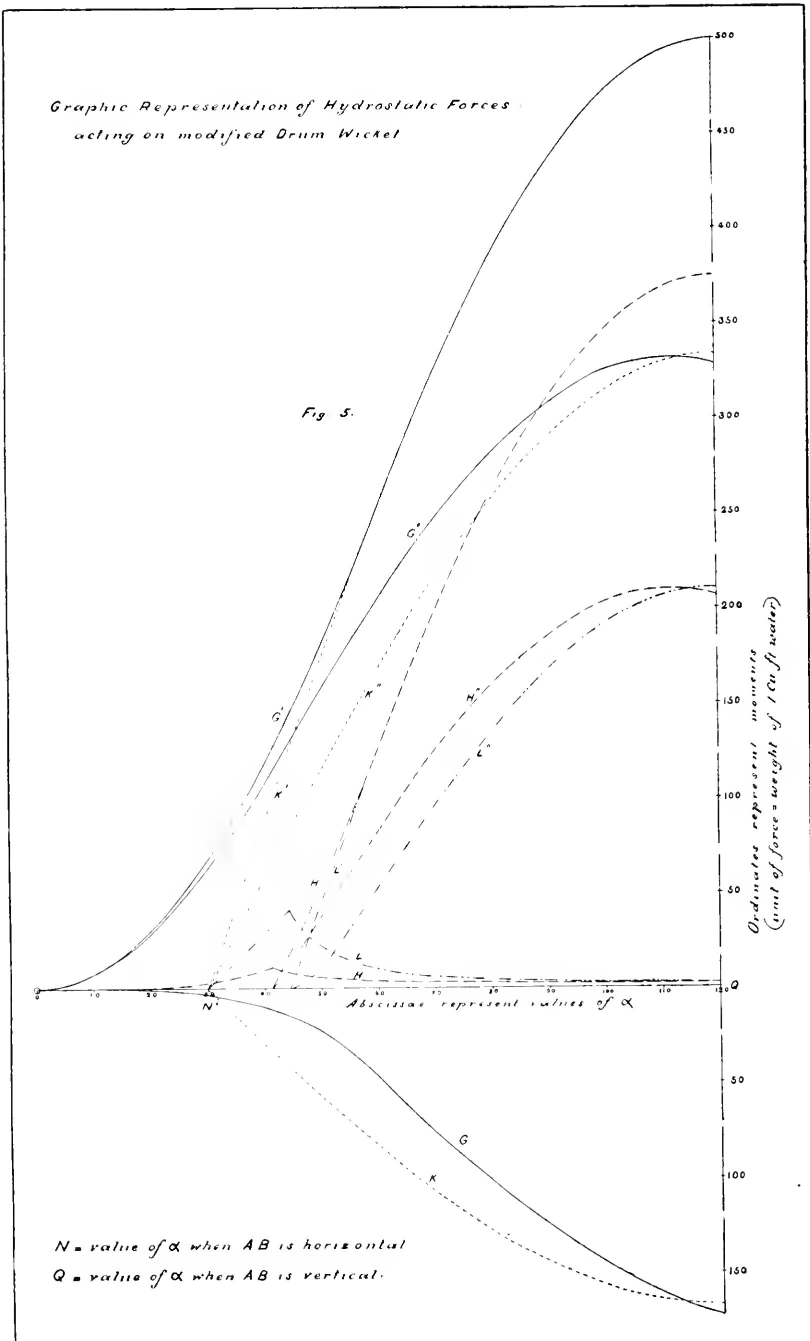
I think there would be no necessity for making the lower leaf longer than the upper, as intimated in Mr. Powell's paper, if the upper leaf were given a moderate curvature, as in the drawing. It is manifest that, for any ordinary stage of backwater, the upper surface of the gate, if of curved form, would emerge at some point between its upper and lower edges, and that the pressure area would then be considerably less for the upper leaf than for the lower. The following analysis shows the effect of such an arrangement. (See Figures 1, 2, 3 and 4).

Let M' = downward moment about point A due to pressure of head h' on cylindrical surface ACB.

" M'' = upward moment on reverse side of same leaf due to backwater h''.

" M''' = upward moment on lower leaf of gate due to difference of head $(h' - h'')$.

" P = pressure per unit of surface at any point, C, due to head $h' - h$.



Graphic Representation of Hydrostatic Forces acting on modified Drum Wicket
Fig. 5.
Ordinates represent moments (unit of force = weight of 1 Cu ft water)
Abscissae represent values of α
N = value of α when AB is horizontal
Q = value of α when AB is vertical.

Let P' = component of P perpendicular to radius vector AC.
" h = vertical distance from horizontal line AX, to any point, C, of curve ACB.
" h' = vertical distance from horizontal AX to surface of water.
" h'' = depth of backwater.
" α = angle of revolution $B'AB$ from origin of motion AB'.
" β = angle between tangent to curve at point A and radius vector from point A to any point, C, of curve. β' is the particular value of β, corresponding to point at which curve ACB meets water surface.
" β'' = $B'AX$ = angle between origin of motion AB', and horizontal line AX.
" ρ = radius vector from point A to any point, C, of curve. ρ' is the particular value of ρ corresponding to point at which curve meets water surface.
" R = radius of curve ACB.
" l = length, AE, of lower leaf of gate (Fig. 4).

In order to arrive at the action of the hydrostatic forces alone, and to determine their maximum effect, let the gate be assumed as without weight or friction, and as rising no faster than the pool behind it. The first two of these conditions can be approximately realized in practice by a proper construction of the gate. The third condition could never be realized, because the great surplus of lifting power would raise the gate to its full height much faster than the pool could follow.

We may now write the following equations:

First.—For the case of a cylindrical surface for the upper leaf.

$$M' = \int_0^s \rho\, P'.\, ds = \text{(see Fig. 2)} \int_0^{\rho'} \rho\, .\, P\, .\, d\rho = \int_0^{\rho'} \rho\, .\, (h' - h)\, .\, d\rho$$

$$h' = \rho'\, .\, \sin\,(\alpha - \beta') \qquad h = \beta\, .\, \sin\,(\alpha - \beta)$$

$$\rho = 2\, R\, .\, \sin\beta \qquad d\rho = 2\, R\, .\cos\beta\, .\, d\beta$$

substituting and integrating, we have

$$M' = R^3\, [4 \sin^3\beta'\, .\, \sin\,(\alpha - \beta') + 2 \cos\alpha\, \sin^4\beta' + 2 \sin\alpha\, \sin\beta' \cos^3\beta' - \sin\alpha\, \sin\beta' \cos\beta' - \sin\alpha\, .\, \beta'] \quad (1)$$

Equation (1) may be used to determine also the upward moments due to backwater h'', by substituting for β' its value, as determined from the following equations:

$$\rho'\, .\, \sin\,(\alpha - \beta') = h'' \qquad \rho' = 2\, R \sin\beta'$$

For the equation of moments due to pressure on the lower leaf, upon which the upward movement of the gate depends, we have

$$M''' = R\, .\, l^2 \sin\beta' \sin\,(\alpha - \beta') - \tfrac{1}{2}\, l^2\, h'' \qquad (2)$$

Second.—For the case of a plane surface for the upper leaf.

$$M_{,} = \frac{\rho'^3 \sin(\alpha - \beta'')}{6} \qquad (3)$$

$$M_{,,} = \frac{h''^3}{6 \sin^2(\alpha - \beta'')} \qquad (4)$$

$$M_{,,,} = \tfrac{1}{2} \rho' l^2 \sin(\alpha - \beta'') - \tfrac{1}{2} l^2 h'' \qquad (5)$$

In these last three equations the origin of motion is taken as AB', the same as in the case of equations (1) and (2), for the sake of algebraic and graphic comparison. In practice β'' would generally be zero and the equations would be correspondingly simplified.

These equations are graphically represented in the curves, shown in Fig. 5, the particular assumptions being $R = 10$ feet, and $\beta'' = 30°$.

EXPLANATION OF CURVES.

First—For the case of no backwater.

G = curve of downward moment due to pressure of upper pool on convex cylindrical surface ACB (Fig. 1).

G' = curve of upward moment due to pressure of upper pool (h') on lower leaf of gate.

G'' = resultant curve obtained by combining G and G'.

K, K' and K'' are corresponding curves in which the upper leaf of the gate is taken as a plane surface.

Second—For the case of an assumed backwater equal to $\frac{1}{4}$ AB (Fig. 1).

G = same as above.

H = curve of upward moment due to pressure of backwater on reverse or concave side of cylindrical surface ACB (Fig. 1).

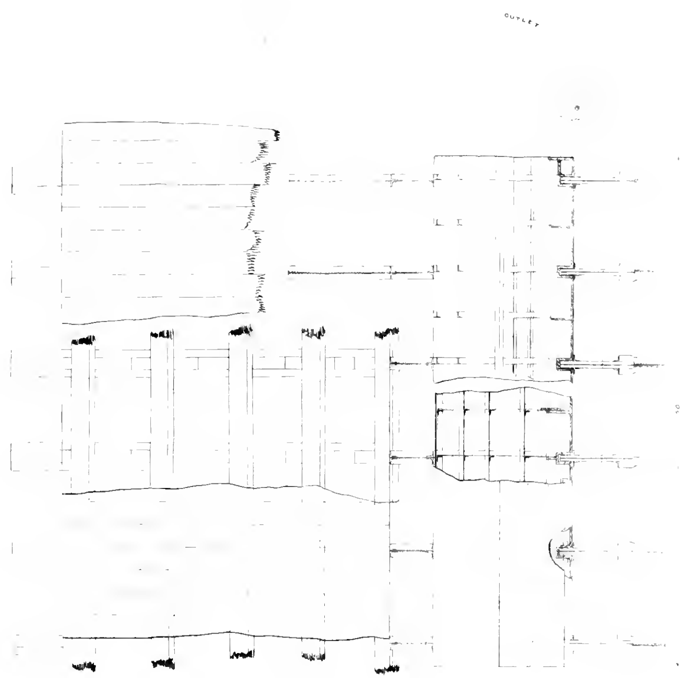
H' = curve of upward moment due to pressure (h'--h'') on lower leaf of gate.

H'' = resultant curve obtained by combining G, H and H'.

K, L, L' and L'' are corresponding curves in which the upper leaf of the gate is a plane surface.

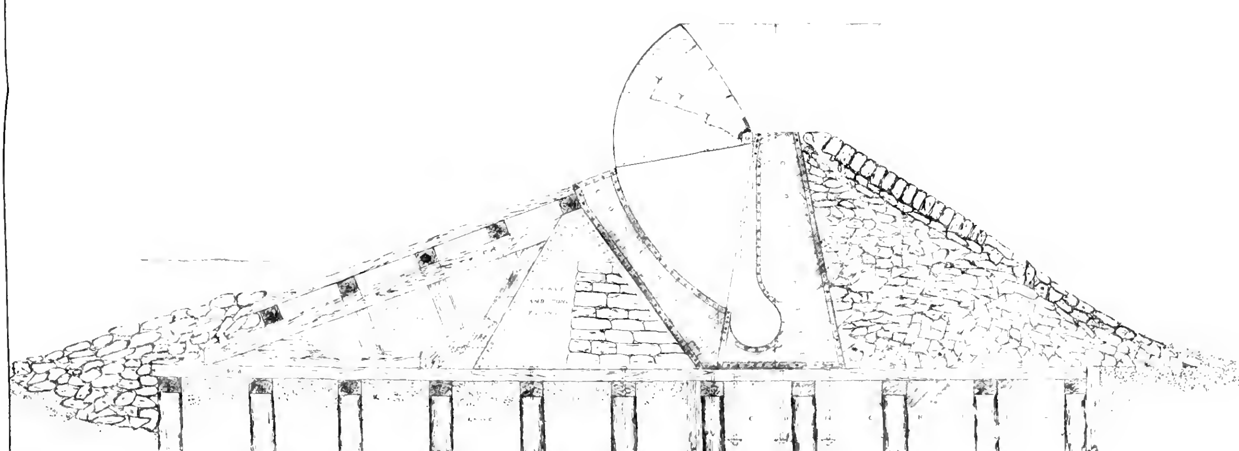
These curves show clearly the considerable gain resulting from the cylindrical form of the upper leaf. With full data for a particular site, the gate could readily be designed so as to give a safe preponderance of upward over downward pressure as it emerges from the pool.

In sites like those shown in the accompanying drawing, where there will always be a considerable initial head whenever it is desired to raise the gate, the lower leaf can be made somewhat shorter than the upper and still provide ample power to operate the gate. The depth of the chamber could, in such cases, be materially diminished.



PLAN

THE
MODIFIED DRUM WICKET



CROSS SECTION

It should be noted, as an advantageous feature in this form of gate, that the rigidity of construction rendered possible will effectually prevent any tendency to warping or binding such as has been experienced in certain other forms, particularly in the case of the old bear-trap.

The gate requires no chain or other form of stop to arrest motion when it has reached its proper height. The automatic release of water from the chamber accomplishes the same purpose without shock to the structure.

Not the least valuable feature of this form of gate is the fact that it is an enclosed ponton, which can be filled or emptied at the will of the operator on shore. To accomplish this, it needs only a pipe extending the entire length of the dam, with branch pipes, controlled by valves, leading to the interior of each gate, and the whole connected with a pump of suitable capacity on shore. The operation of the gate is thus made independent of the question of initial head, and the gate can be raised or lowered even when the water stands at a level above it.

I take this opportunity of correcting an erroneous impression to which my article in the *Engineering News* of February 7, 1895, seems to have given rise among the advocates of the Lang pattern of movable gate. The term "efficiency," as it appears in the extract quoted by Mr. Powell, p. 22 of this paper, was used solely in a technical sense to indicate "ratio of height to base," as Mr. Powell has elsewhere defined it. It had no reference to the general merits of the gate.

VII. Lifting Dam.

By Amos Stickney, Lieut. Colonel, Corps of Engineers, U. S. A.

The movable dam here described is one designed by the writer for closing the navigable pass at Dam No. 6, Ohio River.

CONSTRUCTION.

The pass* is 600 feet in width, and the dam for closing it is divided into twelve equal sections, operated either together or in divisions of three sections each, and the arrangements for operating will permit, by proper manipulation of valves, the lifting or dropping of any division separately or of all the divisions simultaneously. Each section is about forty-nine feet in length, and the space between two sections is about one foot. Each section, when down, is in a chamber, the upstream and downstream walls of which are of concrete. The walls separating adjacent chambers are of 12-inch white oak timbers. The sections of the dam are constructed of white oak and white pine or fir, strongly bound together and

* See figure, p. 257.

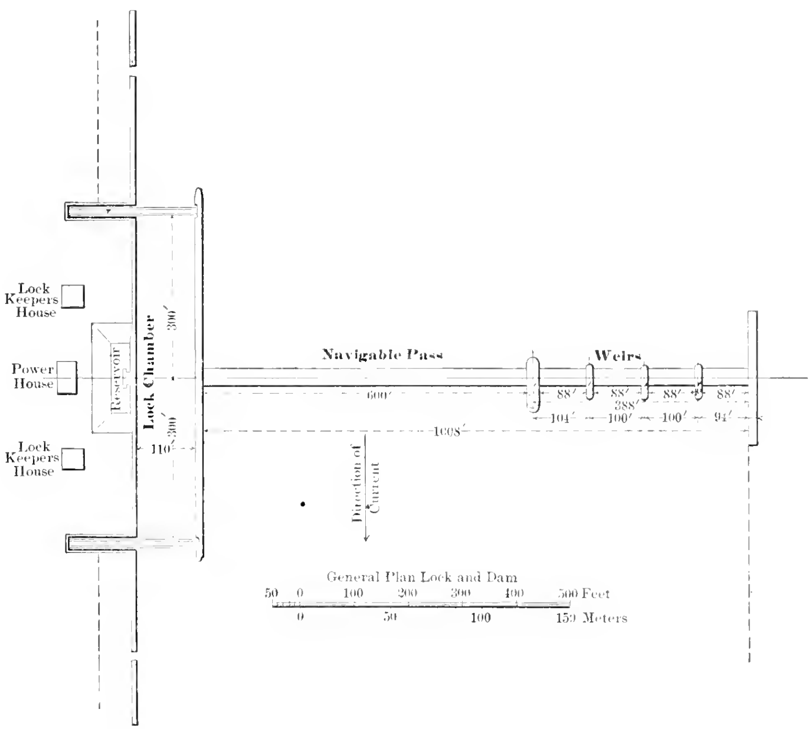
braced, forming stiff cellular structures, so arranged, that whatever position they may occupy, nearly every timber of the structures is constantly in contact with and saturated with water. The purpose of this feature is to prevent or retard decay. A section, in rising or falling, presses against a series of rollers on a shaft along the top of the downstream wall, the upper part of the section revolving around the foot line of the steel props, which are fastened to pins on a line along the top of the section. When the section is up, it rests in a slanting position, with the bottom against the rollers, and the top against the props, and is prevented by stoppers from leaving the chamber. The section is lifted by the pressure of water under the head maintained in a reservoir back of the lock wall, and afterward kept in position by the pressure due to the head of the upper pool, the water in the chamber being connected with the upper pool. The section is dropped by cutting off the connection between the chamber and the upper pool and making connection between the chamber and the lower pool, the section dropping by the preponderance of its weight over that of the displaced water.

In the mass of concrete forming the upstream wall of the chambers is a tunnel, 9 feet in diameter, lined with vitrified brick. This is the filling tunnel, and extends from the river wall of the lock to the pier on the outer side of the pass. Each chamber is supplied with water from the filling tunnel by four iron pipes, 2 feet in diameter. These pipes start from the tunnel above the bottom line so as not to receive any sediment that may settle in the tunnel, and they deliver the water in pits, at the bottom of the chamber under the section of dam. Each pipe is closed by a balanced valve operated by a rod extending to the lock wall, or to the pier. The valves are connected in groups of twelve on one rod, that is the valves for three sections of dam are operated together. Two rods, each operating three sections, are manipulated by a lever on the lock wall, and two rods, each operating three sections, are manipulated by a lever on the pier. The discharge tunnel, with the connecting pipes, in the downstream chamber wall, is similar to the filling tunnel, but placed at a lower level to facilitate the passing of any sediment that may find its way into the pits at the bottom of the chambers. The filling and discharge tunnels have such large cross-sectional area, as compared with the areas of the connecting pipes, that equable pressures will be maintained in all parts of each chamber.

The reduction of pressure in a chamber, due to leakage, when the section is up, is largely prevented by the free supply of water, and the arrangement of packing where the section emerges from the chamber. The packing on the downstream side is a timber, supported on arms which hold it against the face of the dam, while revolving on the roller shaft. The timber has a slight motion on the arms, so that it can be

closely pressed against the dam by the water. The upstream packing is a timber which has a very slight horizontal motion up and down stream, which enables it to follow the movement of the upstream face of the dam.

From an examination of the drawings it will be seen that there is very little opportunity for gravel, or other sediment (except such as is held in suspension in the water) to get into the tunnels or chambers; and if any should get in, it can be easily and effectually removed by sluicing. Any such accumulation in the chambers passes into the discharge tunnel, while that in the tunnels passes into the pier, from which it would be



General Plan Lock and Dam

sluiced out through the sloping conduit leading into the river at the lower end of pier.

The foot of each permanent prop is of a peculiar hook shape, so that it can be lifted off the pin, in case a log or other drift gets under the prop while the dam is dropping. To provide against the contingency of the closing of the water inlets by the matting of small drift on the screens, and to insure against the dropping of the dam, movable props are provided, which are to be placed from a boat, on the upstream side of the dam.

The reservoir, to furnish water under a sufficient head for the initial

lifting of the dam, is constructed back of the land wall of the lock and has sufficient capacity to lift the whole dam to its full height. It is filled by natural flow through a conduit from the lock chamber while the river is at a high stage, but can be filled at any time, or at any stage of the river, by a pump in the pump well. There are two tunnels each 6 feet in diameter, leading from the reservoir under the lock chamber, to the filling and discharge tunnels. These are closed, at the reservoir, by large, horizontal, balanced valves, and each has a connection with the pump well. The pump in the well serves two purposes: first, the filling of the reservoir when necessary; and, second, the emptying of the tunnels when necessary, so that they can be entered from the wells in the lock wall and in the pier. The pump could be run by an ordinary steam engine, but I should prefer an electric engine, connected directly with the pump shaft, the current being furnished by a dynamo in the power house. Submarine cables should pass through the tunnels to furnish light on the pier, and with the necessary connections for attaching lamps in the tunnels.

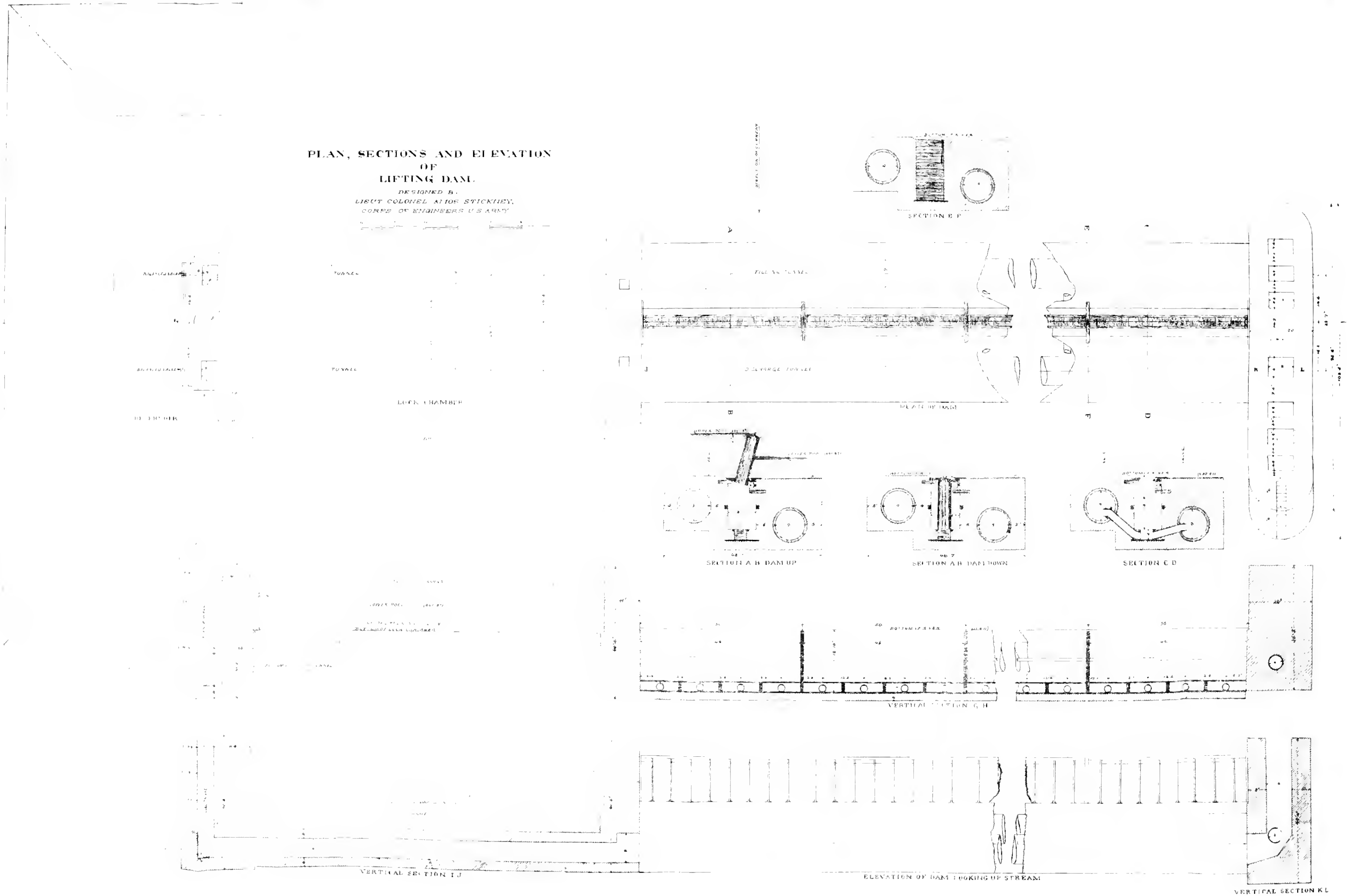
OPERATION.

There are different methods of operating, varying with the order in which the various valves are manipulated; and by any of the methods the entire dam could be lifted at once, or it could be lifted by divisions of three sections each.

The following is one method of operating:

The dam is supposed to be down, lock gates open, and the river flowing freely. The reservoir is supposed to be full, having been filled by flow from the river at a higher stage, or pumped full. All inlet valves for the dam are closed, all outlet valves open, preventing any upward pressure in the chambers.

The first operation would be the closing of the lower gate of the lock chamber. Then, to lift the entire dam at once, close the discharge valves in the pier; open the valves in the pipes leading from the filling tunnel; open the reservoir valves for one or both tunnels. The water from the reservoir will then flow into the chambers from one or both tunnels, lifting the dam. By the time the level on the dam reaches that of the river surface, sufficient head will have been accumulated for raising the bear traps that close the weirs. The flow of the river being then completely stopped, the upper pool will rapidly rise and develop a pressure on the upstream side of the dam in excess of the back pressure from the lower pool. As the resultant of all pressures on any section of dam outside of its chamber is in a line passing downstream and above the line of the feet of the props, there will be a tendency to revolve around the feet of the props, and this tendency develops a lifting force in addi-


PLAN, SECTIONS AND ELEVATION
OF
LIFTING DAM.
DESIGNED BY
LIEUT COLONEL AMOS STICKNEY,
CORPS OF ENGINEERS U.S. ARMY
LOCK CHAMBER
SECTION E F
PLAN OF DAM
SECTION A B DAM UP
SECTION A B DAM DOWN
SECTION C D
VERTICAL SECTION G H
VERTICAL SECTION I J
ELEVATION OF DAM LOOKING UP STREAM
VERTICAL SECTION K L

the feet of the props, and this tendency develops a lifting force in addi-

tion to the pressure in the chamber. When the upper pool has risen sufficiently, the inlet valves in the pier should be opened, thus enlarging the supply of water, under pool head, to the chambers. When the dam is lifted to its full height, the movable upstream props and joint covers may be placed at leisure. The dropping of the dam would be accomplished by a reversal of the operations for lifting. By a study of the valves it will readily be seen how the dam could be lifted or dropped in various ways, and in its entirety, or by divisions of three sections. Less than twelve inches of head will move the dam, and this might be reduced by giving the structures a little more buoyancy, and the necessary head could be obtained, in a stream of considerable slope, without a reservoir, by laying an inlet pipe some distance upstream.

It is probable that if it should be found desirable, the dam could be dropped part way and held, by regulating the pressure in the chambers through partial opening of discharge valves. All valves in the dam are balanced, and are operated by turning hand levers 180°. One man on the lock wall, and one on the pier, could in a very few minutes manipulate all valves necessary for lifting or dropping the dam.

In all cases where more than one valve is operated by one motion, the valve stems are connected with the throwing rod by spiral springs, so that if clogging prevents one valve from completely closing, it will not prevent the others from closing. This device has operated very successfully at the Davis Island Lock.

ADVANTAGES.

The advantages of this type of movable dam are many, and of a nature to justify a considerable increase in cost of construction over that of other types that have not the same advantages.

First, the rapidity and ease with which the dam may be lifted or dropped, thus damming or throwing open a river in a few minutes, is an advantage of incalculable benefit in a river subject to sudden rises. It does away with the requirement of a nice judgment as to the exact time for lifting or dropping the dam, and the possible serious consequences arising from inability to quickly change the river from one state to another; and it does away with the necessity of any elaborate or costly arrangement for notifying the operatives as to the condition of the river above the dam.

The second advantage is in the comparatively small amount of leakage through the dam. In many of the types of movable dams the leakage is so great as to render it exceedingly difficult to maintain a full pool in the dry season, when the flow of the river is very small.

The third advantage is that only a small force is required for operating.

The fourth advantage is in the safety of the men operating the dam, in any kind of weather, day or night.

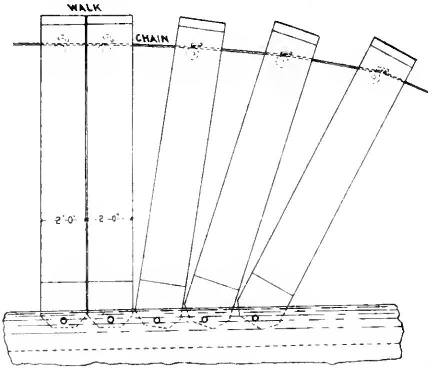
Another advantage, not to be overlooked, is the ability to maneuver the dam under any conditions of the river, even with the water flowing over the dam, so that the safety of the structure itself is not dependent upon the watchfulness and forewarning of the operatives.

VIII. A Design for a Movable Dam.

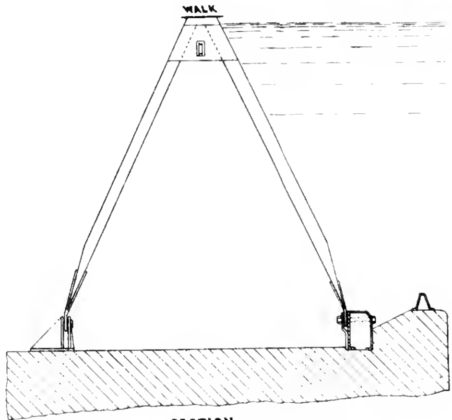
By B. F. Thomas, U. S. Asst. Engineer, Mem. Am. Soc. C. E.

In raising a Chanoine wicket dam, as now constructed, it is first necessary to raise a series of trestles for a service bridge from which to erect the wickets; then a winch is moved along this bridge, and each wicket is raised separately. At best the process is slow and laborious. To lower the wickets, the winch is again moved along the bridge and the wickets are first pulled upstream a few inches, against all the head of water, and then released. After they are all lowered, the trestles are let down one by one. The wickets and trestles have long chains attached to them for maneuvering. In a needle dam the trestles are raised precisely as in a wicket dam. They are connected by bars below the floor level. The needles are then placed from the top of the bridge by plunging them into the water, the foot striking a sill and the head resting against the connecting bar. To lower the needles these connecting bars are released at one end, permitting the needles to fall. A rope is passed through their heads and attached to the bridge so that they cannot float off. After the needles have all been released the trestles are lowered, the ropes holding the needles being tied to a long line fastened to the lock-wall. The Poirée trestle was first used as a support for the heads of needles; next, for a service bridge from which to raise and lower wickets, and finally for supporting gates set directly against the upstream face of the trestle. It is used for all these purposes at present. It is now proposed to make the trestle itself do all the work, without the addition of needles, wickets or gates.

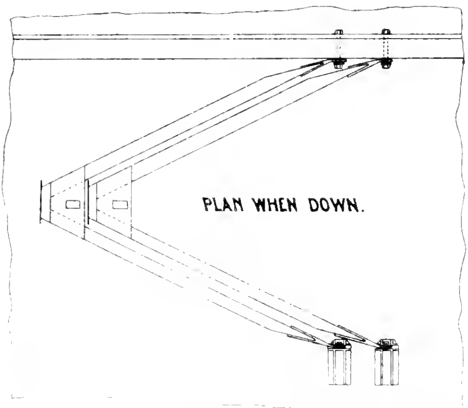
It is evident that in order to accomplish this the trestles must touch each other when standing, otherwise the spaces between them must be closed with an independent construction, a needle. In streams of large discharge this would not be objectionable, but in those of small discharge it might be difficult to keep the pools up during the dry season. Still, even if the trestles were spaced one foot apart and if a joint cover or needle were used when necessary on the whole or a part of the dam, a tighter dam would be secured than those at present in use, either of needles or wickets. But if the trestles are so spaced as to touch each other when standing, how are they to be lowered? In the



ELEVATION.



SECTION.



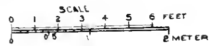
PLAN WHEN DOWN.

DESIGN FOR A MOVABLE DAM,

BY

B.F. THOMAS,

U.S. ASS'T. ENG'R



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first place it is necessary to suppress all diagonal bracing, then suppress the axle and substitute pins for journals. The next thing is to give the posts a decided inclination, the upper one downstream and the lower one upstream. The trestle then has the shape of the letter A. If horizontal braces are retained, they must be placed upon one side only—viz: that which will lie next to the floor when down; but they may project so as to support a neighboring trestle, when up.

Having secured a trestle of this form and design, it will be seen that one will lie flat within another, provided the legs are not too thick, and provided, further, that a sufficient inclination has been given the posts. The boxes which connect the trestle legs to the floor must also be designed in such shape that the trestles will not strike them when down. Having designed a trestle which will hold the water back and will lie on the floor out of harm's way when not needed, it remains only to devise a means for raising and lowering it under all conditions. This is accomplished by means of a chain connecting with each trestle and terminating at a crab on the lock wall. The chain is held on a chain-wheel in the head of each trestle by a guide directly over the wheel. The turning of the wheel may be stopped or started by a ratchet and pawl. The length of chain between two adjoining trestles is greater than their distance between centers, so that several trestles are raised or lowered at once like the sticks of a fan. After the first trestle is up, the hauling in of the spare length of chain between it and the next is effected by releasing the ratchet in the first and allowing the chain to pass on, as the crab is turned. As each trestle comes upright and strikes its neighbor, it automatically releases the pawl from the ratchet. The chain is necessarily much longer than the dam. The length of chain left between successive trestles will, of course, depend on the power of the maneuvering winch—*i. e.*, upon the number of trestles it is desired to have *en route* at one time. In lowering the trestles the pawl is thrown into the ratchet as the chain is paid out by reversing the winch, each trestle being thus made fast to the chain before it starts down. The ratchet can not be released from the pawl till the trestle is raised again.

Details as to pool regulation, walkway above pool level, etc., need not be described here. This style of trestle is applicable to any of the places now occupied by the Poirée trestle, and has the advantage of requiring a much less depth of sill for its protection.

HIGHWAY BRIDGES.

By Carl Gayler, Member of the Engineers' Club of St. Louis.

[Read before the Club, April 15, 1896.*]

In preparing a paper on this subject I have endeavored to bring out a few points which might explain the very limited success of former agitations for an improvement in the building of highway bridges, and to discuss at some length the present practice, not of the highway-bridge companies, but of the structural engineers who have made highway bridges a specialty.

It is now four or five years since the movement for a reform in the highway-bridge business was at its height The technical papers of that time are full of editorials and letters on this question; several prominent engineers and professors of civil engineering devoted their time and influence to it; the Engineers' Clubs of Chicago, St. Louis and Kansas City had committees appointed and reports adopted, and in several States drafts of proposed acts of legislature were prepared and came very near being introduced. And with this the movement came to an end, after having accomplished very little; and highway bridges are being built about in the same manner as before.

As there is no doubt that an improvement in the building of highway bridges is desirable, this failure is remarkable and seems to indicate that the fault lay with the proposed remedies. There is a good deal of force in the objections first raised by Mr. Horton, of the Western Society of Engineers, against the principal proposed remedy, *i.e.*, legislative enactments. It seems unjust to transfer the control over highway bridges from the cities and counties to the State, as the former originate the work, pay for it and have to maintain it.

A perusal of what has been written and proposed at that time leaves, furthermore, the impression that the movement was not sufficiently comprehensive; it might be characterized as efforts to secure legislation providing for expert examinations of the strain sheets of proposed new highway bridges and examinations of such old ones, the safety of which had given rise to doubts. But how about the preliminary work, deciding on the length of span, clear waterway, foundations, character of masonry and—assuming the superstructure to be built according to the proposed State official's directions—the maintenance of the bridge? Surely, every one of these points requires the services of the bridge engineer. Counties will have to follow the example of our large cities, and employ capable engineers for their highway bridges.

* Manuscript received June 20, 1896.—*Secretary, Ass'n of Eng. Socs.*

Wherever in cities and counties public works are in the hands of engineers, State supervision is unwarranted; where county commissioners rely on their own wisdom a limited supervision, as proposed at the time of the late reform movements, is insufficient.

Whenever one of the periodical unusually heavy rains flood a section of the country, we read about a number of bridges having been washed out; such occurrences are generally regarded by the profession with considerable equanimity, as if it were in the natural order of things that abutments and piers are underwashed, or superstructures carried away by floods which surely should never have reached them, whilst the occasional breaking down of a highway bridge is carefully noted, and still gives rise to spasmodic appeals for legislation. Why this important question of sub-foundations was never included in the efforts of the reformers, why it is likewise hardly ever mentioned in books and treatises on highway bridges, has always been a mystery to the writer. Some remarks on this subject may not be out of place.

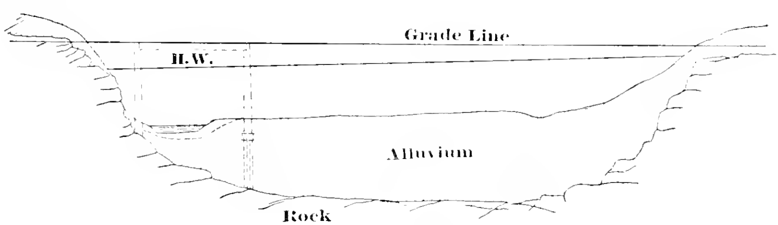


Fig. 1

The cross-section of a valley, as shown in Fig. 1, through which a road is supposed to be built, requiring the crossing of a creek or stream, is typical of the cases with which I had experience; it is probably also typical of the greater number of cases in this part of the country. It is a broad valley, with steep banks and an alluvial bottom. The rock is near the surface on both bluffs, the alluvium extends down to considerable depth, and the water-course is near one of the two banks. A glance will show this valley to have been in former ages the bed of a great river, which, probably assisted by the action of ice, hollowed out its immense bed in the rocks. Subsequent sinking of the land or diminishing of the volume of water, or both causes combined, raised the level of the bed of the river, and the valley filled up with boulders, gravel or sand, or with clay, from the ice period, and, closer to the present water-course, with more recent deposits. To form an intelligent judgment of the contemplated foundations, an insight into the history of the valley in by-gone ages, assisted by some general knowledge of geology, is necessary. Borings or test-pits will complete what is necessary to plan the foundations and estimate their cost. The grading of the highway and

the building of the substructure reduces the free waterway in time of floods, a deepening of the water channel, often, also, a shifting of the water-course, caused by the dying out of the vegetation, takes place, and these changes in the water-course are most important in designing the foundations and, unless taken well into consideration, will cause the destruction of the bridge in short time.

That this preliminary work, as well as the building of the abutments and piers, should be in the hands of the bridge engineer, will be readily conceded.

The superstructure of the American highway bridge has been developed by the highway-bridge companies, and it has been truly stated in regard to the best examples among them, that "greater strength and safety are obtained from a given amount of materials than with the methods of construction which prevail abroad." During late years, some of our leading structural engineers have given their attention to this subject, and have published books and specifications on highway bridges. A subdivision of the latter into three classes, according to their proximity to cities, assuming different live loads for each of them, is now the accepted rule. Being more familiar with Class I (or A), *i.e.*, bridges in cities, I will confine part of the following remarks to this class.

It is generally agreed to assume for the live load, beside a concentrated load by which the dimensions of the flooring, stringers, floor-beams and hangers are obtained, a uniform load per square foot, covering the whole and portions of the bridge, ranging from 100 pounds for short spans to 50 pounds for longer spans. It is worth while to consider what this assumed uniform live load really means.

In the case of railroad bridges the live load is simply the weight of the trains, and the unit strains in the truss members have been selected of such magnitude as to give a structure of reasonable rigidity. For the principal tensile members, 10,000 or 12,000 pounds are customary, and for the compression members a reduction is made in the units according to the laws of the strength of columns. These unit strains are far lower than the elastic limit of the material would seem to warrant: they bear no relation to the breaking strength, and the so-called factor of safety may as well be abandoned as an antiquated expression without meaning; they have been evolved from the behavior of bridges under their daily duties. As Prof. J. P. Snow, in a recent discussion on the strength of iron railroad bridges, puts it: "What is the basis of the present units? Examinations of bridges in service. In order that a bridge may be satisfactory it must remain rigid under trains and deflect but very little. These conditions can only be obtained by using low units." Now, with highway bridges the case has just been reversed. We start out with unit strains borrowed from the railroad bridge practice

(increasing them, however, about 25 per cent., for some reason not easily explained) and then choose the live load with the view of obtaining a satisfactory structure. It is well to keep this in mind; attempts to explain the customary live loads for highway bridges in any other way are misleading, if not dangerous.

Since the substitution of steel for iron, some engineers specify for highway bridges of the former material an increase in the unit strains of 20 per cent. Granted that the ultimate strength of steel is 20 per cent. greater than that of iron, and the elastic limit even more, this increase in the units is, for the reasons stated above, not justified, as the modulus of elasticity of steel exceeds that of iron but little. By far the greater number of highway bridges, with their plank floors, are light structures; there is little mass in the metal to overcome the effects of the jolting of wagons over the rough planks, or of the trotting of horses; the vibrations are accumulative and we should be slow in adopting an increase of units. Increasing, or doubling the units for the dead load should only be resorted to for very long spans, or for bridges with extremely heavy floors. I may be permitted to state here that my experience in this city with four steel spans of 120, 135, 150 and 220 feet length, designed for the live load of Cooper's A, but for unit strains of iron railroad bridges, no increase in them being made for units under dead load, has been such that I have never felt guilty of a waste of material in designing them, and that they have convinced me that the usual specifications for this class are too light.

Specifications and books on highway bridges and standard details for the same, as published in the latest works, have left the impression on the writer that this subject has not been treated with the conscientious care bestowed on other structural work. Whether the temporary and unsatisfactory character of most of the floors, or the fact that bridges built in accordance with these books and specifications are still far above the general practice all over the country, or the certainty that the bridges when completed will in nine cases out of ten be neglected and go to wreck and ruin anyway, can explain their neglect, I am unable to say.

The consideration of rigidity, which have led to the selection of these live loads, should be the guide in regard to lateral connections and the results of our experience with railroad bridges should with equal care be applied to the highway bridge. In all through spans rigid connections of floorbeams with posts and bottom chords should be insisted upon, not that perfectly safe hangers could not be designed—the latter having even a slight advantage in applying the load centrally to the posts—but the gain in lateral stiffness is too great to be thrown away. It is impossible to prevent altogether a distortion of the structure in a storm or under a

load applied close to one of the two trusses; but with deep floorbeams well riveted to the posts and top lateral struts firmly attached to top and bottom of the top chord, as sketched in Fig. 2, considerable resistance is gained, with details as shown in Fig. 3, next to none.

There is one feature in through bridges to which never yet full justice has been done; it is the top lateral bracing. The universal custom is to design it to withstand the wind pressure (generally assumed to be 150 pounds per linear foot of top chord). Now there is not the least doubt that it should be made strong enough to resist the wind forces, but there is just as little doubt that if a bridge were thoroughly protected against wind, the top lateral system would still have to prevent the top chord from buckling; more than that, I am convinced that no storm ever strains

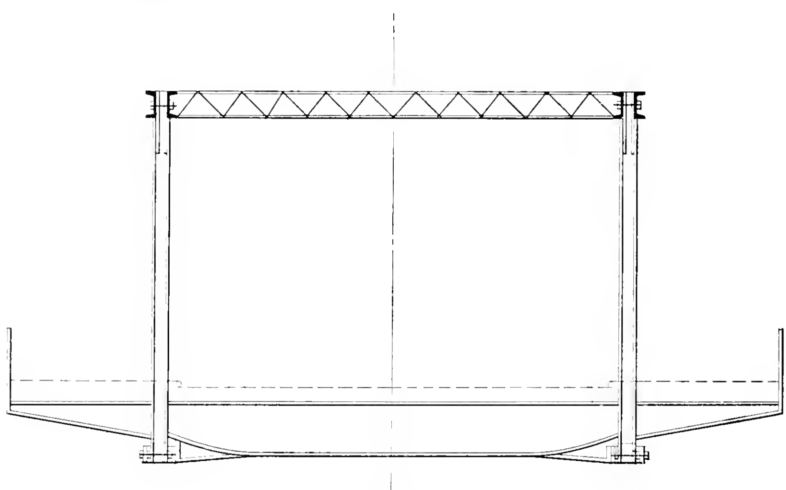


Fig. 2

it as the top chords do under their full duty. Anyone standing on a railroad bridge with a train moving over it can satisfy himself on this point. It seems to be against sound judgment to design the top lateral system of a through span on the same supposition as the bottom lateral system of a deck span. This is one of the many instances where the strain sheet alone is no sufficient guide. The engineer has to use his experience and judgment to design a lateral system of sufficient rigidity; no theory in the world will enlighten him on the amount of lateral pressure exerted by an exceedingly long column. Mr. Waddell, in his book on highway bridges, states in this respect, without, however, entering into the question, that the top lateral rods in highway bridges up to 200 or 230 feet length, if proportioned for wind pressure alone, are too light.

The above remark that the strain sheet does not cover every case

applies with equal force to the specifications. It has been too much the custom to let highway bridges under a set of specifications, limiting the work of the consulting engineer—in case an engineer is consulted at all—to checking the figures and sizes. This custom, more than anything else, has made a highway bridge superstructure a mere merchandise. Nothing is, for instance, easier than to specify "a substantial railing" for a bridge, yet nothing is more indefinite and more difficult to enforce. Specifications are necessary, but we need even more the judgment of the engineer; we need more designing and less standards.

I have no intention of entering into the question of the relative superiority of pin-connected or riveted highway bridges, but there is one type in which the latter are infinitely superior to the former, *i. e.*,

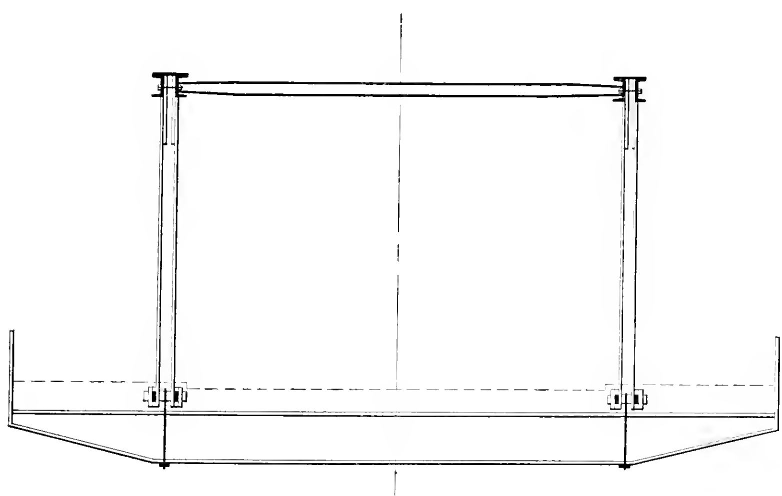


Fig. 3

the short span pony truss. If designed with pin connections the lack of lateral stiffness is exceedingly difficult to overcome; with a riveted design we easily obtain a most excellent structure.

The subject of floor systems could easily be made to take up your whole time for an evening, and will not be discussed beyond calling attention to the new departure which has been occasioned through the advent of the electric motor car. That it will be of the very greatest moment is apparent; we have in this city motor cars, weighing, when crowded with people, 24 tons, carried on two trucks 25 feet apart; we have others of 18 tons weight when full of people, the trucks being spaced 14 feet between centers. In the first motor cars the load on each truck was distributed equally on both axles; to gain in tractive force the pin was

then shifted so that about 75 per cent. of the load came on one axle, and in the latest cars (on Jefferson and Grand Aves.) the whole weight is carried on the driving axles. The first motors of 15 horse-power have been succeeded by 25 and 50 horse-power motors; girder rails 6, 8 and 10 inches deep have taken the place of the flat rail of the old street cars. It is not more than six years since electricity began to be generally applied to the city and suburban transportation, and it is not likely that the motor car, especially on long suburban lines with heavy grades, has attained its greatest weight.

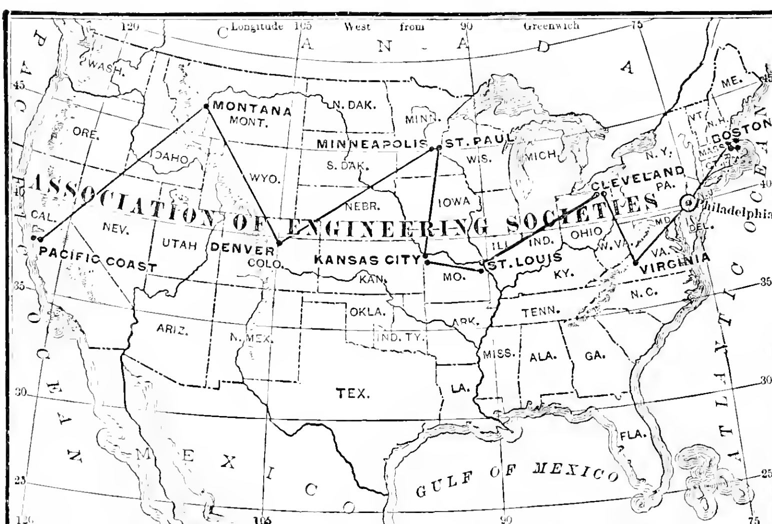
Assuming now a bridge to be completed, the work of the engineer is still not over. In a few years the floor will need looking after, parts of the ironwork and railing require attention and the paint will begin to show those ugly spots which indicate that the work of deterioration has begun. This question of painting is the bane of the structural engineer's life, the one point where his knowledge is at fault and where his only recourse is to get the rust scratched off and new paint smeared over it. It does not matter very much what kind of paint he uses, iron oxide, lead paint or asphalt, so long as he tries to get a good brand and makes the most of his limited knowledge of the oil and the pigment; in all probability he will use them all in turns and in turns be disappointed. Protection of metal against atmospheric influences by paint applied cold is temporary.

Rusting is most to be feared and most difficult to prevent on surfaces which are close together without being in close contact throughout, as at pin joints between the heads of eyebars and the adjacent portions of the posts and chords. Taking apart old pin-connected trusses we find the greatest corrosion on the sides of eyebar heads. It should not seem to be impossible to remedy this by filling these spaces with an impervious material; to my knowledge this has been successfully done on the lower chords of the heavy Pauli trusses of the Monongahela bridge at Pittsburgh. In riveted work there is no excuse for such dangerous spaces between different members, but we still find too often, through faulty riveting or where rivets have been spaced too far apart, that we can insert the blade of a knife between angles and plates, especially at the stiffness of large web sheets.

Such weak points will probably never be quite overcome; the wonderful example of the Eads bridge, where the sides of the eyebar heads of the main arches and the adjacent sides of the joint blocks were planed and all the exposed joints of the covers of the tubes were carefully caulked, will never be imitated, but the designer of structural work should keep this question always in mind.

The action of corrosion in wrought-iron work in cases where painting is utterly unavailing—and it has been my luck to have a number of

such cases under my charge—is peculiar. A hard shell of corroded iron of pretty uniform thickness forms over the whole exposed surface; this shell scales off to make room for the formation of another shell, and this process goes on until nothing is left to scale off. It might not unreasonably be supposed that this process of scaling off in layers is peculiar to wrought iron as a material rolled and welded in layers, and that steel, being a homogeneous, crystalline metal, would better resist the attack of rust. Should this prove to be true, what a splendid bargain did we make in exchanging iron for steel!



Bradley & Poates, Engr's, N.Y.

ASSOCIATION

OF

ENGINEERING SOCIETIES.

VOL. XVI. JANUARY, 1896. No. 1.

PROCEEDINGS.

Civil Engineers' Society of St. Paul.

ST. PAUL, MINN., JANUARY 6, 1896.—Regular meeting of the Civil Engineers' Society, held at 8.15 P.M. Thirteen members and one visitor in attendance. President Stevens in the chair. Amended minutes of previous meeting read and approved. The government of the Society was requested to report a proposed amendment to the constitution to cover settlements with delinquent members. The annual reports were read and placed on file. The Librarian was authorized to arrange for a year's subscription to the following periodicals: *Engineering Magazine, Engineering News, Engineering Record, Engineering, Trans. Am. Soc. M. E., Trans. Am. Inst. E. E.* The Librarian was also requested to procure the current *Proceedings of the Engineers' Club of Philadelphia* by exchange, if possible. Mr. W. L. Darling was elected a member. The present incumbents of all offices were re-elected. Upon motion, a committee of three was appointed to consider and report upon so much of the Parker Retrenchment Committee's Report as related to the City Engineer's department. C. F. Loweth, A. O. Powell and J. D. Estabrook constitute the said committee. Mr. A. H. Hogeland led the discussion of the evening with a description of the effect of earth slides on the Great Northern Railway bridges which cross the Red River of the North and its tributaries. Mr. C. F. Loweth explained and illustrated the circumstances of the movement of Pier No. 1 of the Northern Pacific Bridge at Bismarck. Immediately before adjournment the President appointed the following gentlemen to serve on the Examining Board for the ensuing year: A. O. Powell, J. H. Armstrong and Oliver Crosby. Mr. Loweth was appointed to audit the accounts of the year just closed.

C. L. ANNAN, *Secretary.*

JANUARY 20, 1896.—The Civil Engineers' Society of St. Paul held its annual dinner, followed by a special meeting, at the Windsor Hotel, to receive the report of the special committee appointed to investigate the justice and accuracy of the recommendations of the retrenchment committee upon the city engineering department. The report was a strong and exhaustive one, completely refuting the insinuations of extravagance made by the retrenchment committee against the City Engineer's department. It was unanimously adopted.

The committee appointed by the Civil Engineers' Society to make the investi-

gation reported informally that it had spent several days in making the investigation. It had gone through the books of the engineer's office thoroughly, and grouped the facts. It had ransacked the office from top to bottom, and was convinced that its conclusions were correct. How much work had been done by the committee might be gathered from the fact that one of the sessions lasted twelve consecutive hours, and that ten hours alone was spent in "boiling down" the first draft of the report, so as to make it concise and pointed. The consequence was that the committee had a multitude of facts and figures in abeyance, all tending to prove and support its conclusions.

The personnel of the committee carried great weight with the members of the society, as all the members were men of exceptional experience and conservatism. The members were C. F. Loweth, chairman; A. O. Powell and John D. Estabrook.

The apparent disposition to abandon the manual training school was discussed after the committee's report was disposed of. President H. E. Stevens and Messrs. Estabrook, Woodman, Loweth and Crosby all expressed it as the result of their individual observations that the school was a most important adjunct to the city's educational system. In conclusion, a resolution offered by Mr. Crosby, protesting against the disposition to curtail the usefulness of the school, was adopted.

C. L. ANNAN, *Secretary.*

Technical Society of the Pacific Coast.

REGULAR MEETING, held January 3, 1896.—Called to order at 8.30 P.M., by President Dickie.

Minutes of the last regular meeting read and approved. The Nominating Committee selected at the last regular meeting submitted the following report through its chairman:

To the President and Members of the Technical Society of the Pacific Coast: Your Committee on Nominations for the offices to be filled at the Annual Meeting desire to report the following ticket :

President—Geo. W. Dickie.
Vice-President—W. G. Curtis.
Secretary—Otto von Geldern.
Treasurer—E. T. Schild.
Director—L. Falkenau.
" W. F. C. Hasson.
" Randell Hunt.
" J. D. Isaacs.
" J. C. Sala.

Very respectfully (for the Committee),

(Signed) C. E. GRUNSKY, *Acting Chairman.*

Mr. John D. Isaacs stated to the Society that he had been prevented from completing a paper for this evening, and that he would submit such paper at the next meeting of the Society.

It was ordered, upon motion, that Mr. Isaacs' paper be read after the regular business of the Annual Meeting to be held January 17th.

The members present discussed the patent laws of the United States informally, after which the meeting adjourned.

OTTO VON GELDERN, *Secretary.*

ANNUAL MEETING held January 17, 1896. Called to order by President Dickie.

Messrs. C. E. Grunsky and Hubert Vischer, having been appointed tellers to count the ballots for the officers of the Society for the ensuing year, they declared the following ticket elected in regular form :

President—Geo. W. Dickie.

Vice-President—G. W. Curtis.

Secretary—Otto von Geldern.

Treasurer—E. T. Schild.

Directors—Louis Falkenau, W. F. C. Hasson, Randell Hunt, J. D. Isaacs, Jos. C. Sala.

The Secretary read his report for the year 1895, which was ordered received and adopted as read.

The reading of Mr. Isaacs' paper was laid over until the next regular meeting of February.

The matter of appointing a Standing Committee to investigate, collect and formulate data that bear upon the character and specific qualities of our Pacific Coast timbers, and to show by experiment and design the best use of modern practice in the manifold ways in which this material is applied, was considered, and upon motion a committee was appointed by the Chair, consisting of Professors Frank Soulé, Albert T. Smith, and Messrs. John D. Isaacs, Randell Hunt and George W. Percy, who are to constitute a Standing Committee on Pacific Coast Timbers.

After discussing the prospects for the coming year and the usefulness of the Society to the industrial pursuits of California, the meeting adjourned.

Attest: OTTO VON GELDERN, *Secretary.*

ABSTRACT OF THE ANNUAL REPORT OF THE SECRETARY FOR THE YEAR 1895.

THE present total membership is 167, as follows:

Honorary members	3
Members	151
Juniors	6
Associates	7
Total	167

Of these 89 are resident and 78 non-resident members.

89 reside in San Francisco and vicinity; 55 in other parts of California.

Professionally divided there are: 3 architects, 66 civil engineers, 4 electrical engineers, 29 mechanical engineers, 18 mining engineers, 12 surveyors.

During the year 1895, the Society added to its membership 18 members and 2 juniors.

MEMBERSHIP OF THE SOCIETY IN JANUARY, 1895.

Members and associates	205
Admitted in 1895	20
Total on membership list in 1895	225

Loss During 1895.

Deaths	5
Resignations	8
Suspensions	45
Total	58
Present membership	167
Decrease in 1895	38
Number of regular meetings held during the last year	10
Social meetings (Banquet)	1

Subjects Read and Discussed.

1. Comparison between Steam and Gasoline Traction Engines. *Ernest F. Rossow.*
2. Transmission of Intelligence by Electricity. *Frank P. Medina.*
3. Stopping a Troublesome Slide at Summit Tunnel. *John D. Isaacs.*
4. Reconstruction of the Car Ferry Transfer Aprons at Port Costa and Benicia. *John B. Leonard.*
5. Engineers: Consulting, Inspecting and Contracting; their Relationship to each other and to the Public. *Geo. W. Dickie.*
6. Some Experiments on Water Ram in Pipes. *Chas. D. Marx.*
7. The Construction of a Large Wrought-Iron Wheel. *Edward S. Cobb.*
8. Pacific Coast Timber; its Tests and Treatment. *Frank Soulé.*
9. The Cyclotomic Method of Transit Observations. *Otto von Geldern.*
10. Released Ashlar: a Problem in Building Construction and Ornamentation. *John Cotter Pelton.*
11. Recent Improvements in Coal Handling Machinery. *John D. Isaacs.*

Of these, numbers 3 and 4 have been published, while the others will appear in print from time to time.

On March 1, 1895, the Technical Society became a member of the Association of Engineering Societies, and its papers were published in the Journal of the Association.

In addition, the Society issued a separate publication of its professional papers, in publishing the reprints of the Association under the title of "Transactions of the Technical Society of the Pacific Coast," January to July, 1895.

This bulletin contains 94 pages with the following

Contents:

Representatives on the Board of Managers are:

W. F. C. Hasson, Electrical Engineer.
Hubert Vischer, Civil Engineer.

The past year of our Society has been a more prosperous one than could have been expected under the existing business depression. While we record a loss of

thirty-eight names over and above the admissions during the year, it must be remembered that many of these members had been in arrears for dues for some time, and were merely allowed to remain on the list, until it was ordered by the Executive Committee that all members, in arrears for over one year, should be placed on a suspension list, and should not be entitled to the publications. Such a course became absolutely necessary in order to avoid incurring an expense for which there was not an immediate return.

For this reason it became necessary to place forty-five members on the Suspension List, and this is the cause for what appears to be a great loss in the active membership of the Society.

Any one of these members may, by paying the arrearage to the date of his suspension, be reinstated to his standing in the Society.

Engineers' Club of St. Louis.

428th Meeting, January 8, 1896.—President Ockerson called the Club to order at 8.10 P.M., at 1600 Lucas Place. Thirty members and one visitor present.

The Executive Committee reported the doings of its 204th and 205th meetings, approving the applications for membership of W. S. Brown, S. F. Crecelius and O. E. Overpeck. They were balloted for and elected.

The Executive Committee recommended that instead of the usual roster there be issued this year an annual bulletin, to include the list of members, officers and committees, constitution, by-laws, programme, etc., which have heretofore appeared in the annual publication; and, in addition, the reports of officers and committees read at the annual meeting, and also the addresses delivered at the annual dinner. A limited number of selected advertisements to be included, with a view of reducing its net cost. On motion, ordered that this matter be left to the discretion of the Executive Committee.

The Secretary reported that a contract had been entered into with the Missouri Historical Society for renewal of the Club's lease for quarters in their building for two years.

The Secretary announced the resignations of J. I. Ayer, J. G. Kelley, W. S. Love and C. B. White, to date December 31, 1895.

Nominations being called for to fill the vacancy in the office of director, Mr. William Bouton was nominated. On motion, ordered that the Secretary cast the ballot of the Club for Mr. Bouton. This was done, and Mr. Bouton declared duly elected director.

The Secretary read letters of regret at their inability to attend our annual dinner from the Presidents of the Minneapolis, St. Paul, San Francisco, Kansas City and Helena Engineers' Clubs.

Mr. Geo. B. Leighton then read a paper on "Some Notes on English Railway Practices." It was illustrated by numerous maps, drawings and pamphlets. The speaker described at some length the essential features of English railways, calling special attention to those points in which their practice differed radically from ours.

The speaker also gave an account of the International Railway Congress held in London in June, 1895, which he had attended, together with some remarks on the social features connected with the meeting.

The discussion was participated in by Messrs. Moore, Crosby, Johnson, Hermann, Kinealy, Russell, Maltby and Pitzman. Adjourned.

William H. Bryan, *Secretary*.

429TH MEETING, JANUARY 22, 1896.—President Ockerson called the Club to order at 8.30 P.M., at 1600 Lucas Place. Twenty-seven members and five visitors present.

The minutes of the 428th meeting were read and approved. The Executive Committee reported the doings of its 206th meeting. Applications for membership were announced from W. G. Comber, U. S. Assistant Engineer; Horace Dunaway, surveyor with Mississippi River Commission; and J. L. Van Ornum, instructor civil engineering, Washington University.

Mr. E. J. Spencer then addressed the Club on "Underground Electrical Service," giving the results of the wide study and varied experience which the speaker had had in work of this character, in different parts of the country. He reviewed the historical features of the subject, explaining the work done both at home and abroad, the difficulties which had been met with and how they had been overcome.

It is not generally known that the first experiments with the Morse telegraph were made with underground circuits; these gave so much trouble that the entire matter was on the point of being dropped, when an assistant suggested trying overhead wires. This being done, the experiment was immediately successful. The speaker explained the work which had been done in New York, Philadelphia, Boston, Chicago, and elsewhere, and regretted the fact that St. Louis was moving so slowly. He stated that there was no city east of St. Louis of 150,000 inhabitants or more, which did not have its wires underground in the business districts. He showed a number of samples of cables of different types and for a wide variety of purposes.

Messrs. Moore, Bryan and Flad participated in the discussion. Adjourned.

WILLIAM H. BRYAN, *Secretary.*

The Civil Engineers' Club of Cleveland.

CLEVELAND, O., JANUARY, 1896.—Meeting of the Civil Engineers' Club of Cleveland, Tuesday evening, January 14th.

Present, 57 members and visitors. In the absence of the regular officers, Mr. Searles was called to the chair. The minutes of the last meetings were read and approved. Messrs. Varney and Cooke were appointed tellers to canvass the ballots for the election of Mr. J. S. Covert.

The Executive Committee reported, in regard to the special Library Fund, that $210 for the year had been subscribed and $175 collected. That the special contract had been arranged with Case Library whereby they were to appropriate as much more as we raise every year to the purchase of technical works, and that a special alcove was now devoted to our use on the second floor of the Case Library building.

All members are requested to send to the Librarian the titles of any books they consider suitable for the Library.

That a Committee, consisting of General Barnett, L. E. Holden and C. H. Strong, had been appointed to draft resolutions upon the death of our brother member, General Leggett. (Owing to the absence of General Barnett from the city, they did not report this evening.)

From the Committee on Coinage, etc., House of Representatives, United

States of America, a bill to fix the standard of weights and measures by the adoption of the metric system. Referred to the Executive Board.

Communication from the Architectural Club, offering the privilege of an evening to be known as the Civil Engineers' Club evening, when the Clubs should visit the exhibition together. Referred to the Executive Board.

The following were appointed a committee to nominate officers for the coming year: S. H. Searles, A. Swasey, A. Mordecai, W. R. Warner, Walter Miller.

The paper of the evening, "Quadruple Expansion Engines for Lake Service," was then read by Mr. Walter Miller. Discussion upon the paper was taken part in by Messrs. Oldham, Newman, Swasey and others. The whole was very interesting.

Mr. W. W. Sly then gave an illustrated talk on "Tunneling Machinery."

After the meeting the Club adjourned to the restaurant and partook of a light lunch. F. A. COBURN, *Secretary.*

Montana Society of Civil Engineers.

THE ninth annual meeting was held in the Society's office at the Board of Trade rooms in Helena, Montana, January 11, 1896. The meeting was called to order at 11.15 A.M.

The members present were: Messrs. Keerl, Smith, Monroe, Bickel, Dewar, McArthur, Ryon, Thorpe, Mumbrue, Cumming, Page, Wickes, Hovey, McRae, Haven and Parker. There were present also about twenty invited guests.

The minutes of the last meeting were read and approved.

The tellers reported that John Randolph Parks and John Cameron Patterson were elected members of the Society.

The following officers were declared unanimously elected for the ensuing year:

President, John Herron; Vice-President, James M. Page; Second Vice-President, A. E. Cumming; Secretary and Librarian, Forrest J. Smith; Treasurer, A. S. Hovey; Trustee for three years, W. A. Haven; Member of the Board of Managers of the Association of Engineering Societies, James S. Keerl.

Applications for membership of Frederick Charles Scheuchs, A. J. Seligman and Frank Joseph Steever, were read. The Secretary was instructed to refer Mr. Steever's application back to him to be made out in more detailed form and handed to the Trustees for approval.

The newly elected First Vice-President took the chair.

The Secretary and Treasurer submitted reports which were referred to the Board of Trustees.

The Committee on Arrangements reported that passes had been secured for the members on the different railroads leading into Helena.

Mr. Keerl, the retiring President, as Chairman of the Committee, extended an invitation to the members of the Society and their guests to a reception at his residence, from eight o'clock until midnight. The invitation was accepted by the Society.

A vote of thanks was extended to the agents and managers of all the railroads who kindly sent passes to members of the Society not residing in Helena.

Two letters of withdrawal were read, one from Albert B. Knight, of Butte, and one from A. F. Whitcomb, of Vermont. The withdrawals were accepted by the Society as provided for by the Statutes, and Mr. Whitcomb was placed on the list of the Associate Members of the Society.

AFTERNOON SESSION.

The retiring President, Mr. James S. Keerl, referred to the progress of the Society during the past year. There had been added to the rolls of the Society twelve new members, and there were added three more during the day. During the year the Society had listened to the reading and discussion of various papers on a variety of appropriate topics, among the best of which was one by an ex-President of the Society, E. H. Beckler, describing a narrow gauge railroad, built for W. A. Clark, in Arizona, for the transportation of copper ores; another by Maurice S Parker, a member of the Society, of Great Falls, on the cost of water and steam power in Montana.

Mr. Keerl then read his address on Relative Standing of Engineering among the Professions.

The subject for discussion before the meeting was a paper formerly read by J. H. Farmer, on "Water Power by Electrical Transmission," in relation to the mills and manufactories of Helena, a synopsis of which is given below:

Amount of dry Montana fir and pine wood consumed in generating one horse-power per hour	4.4 pounds.
Cost of wood per cord, averaging 2 910 pounds	$3.50
Cost of one horse-power, for 365 days of twenty-four hours	70.50
" " " " " " " " " " " "	71.56

using Montana coal.

Estimated cost of one horse-power, generated by water power, and transmitted by electricity to central power-station in Helena:

Cost of dam, power-house, etc., to develop 90.10 horse power on wheel shaft	$6.10 per horse-power,
Transmission to Helena (12 miles)	10.68 " " "
Total fixed charges for 365 days of twenty-four hours, for power delivered in Helena	16.78 " " "
Saving over best steam tests	53.72 " " "

The dam is to be of masonry, of the following dimensions:

Height	30 feet.
Length	740 "
Length of weir section	400 "
Crest width	10 "
Bottom width, at 68 feet depth	50 "

Minimum flow of Missouri River, at Stubbs' Ferry, 200,000 cubic feet per minute.

Mr. Herron presented results of tests of wood and coal at Marysville, Montana, with Corliss Compound Condensing Engine with 14″ and 24″ x 42″ cylinders developing 143 horse-power.

Original cost of plant	$92.00 per horse power
Interest, repairs, etc.	10.00 " " "
Cost of one horse-power for 365 days of twenty-four hours, using Montana coal, at $3.60 per ton, 2,000 pounds	3.69.
Cost of wood, per cord of 2,800 pounds	3.69.
Cost of one horse-power for 365 days of twenty-four hours, using dry pine wood	118.55.

Mr. Parker.—My investigation of the cost of steam power under various conditions and comparative cost of water power, fully bear out the statements made by Mr. Farmer in this connection.

The cost of steam power can readily be determined when cost of fuel is known. That of water power must be ascertained by careful investigation. I find the average cost per horse-power for developing water power, including electrical transmission up to the distance of thirty miles; to be about $2.00 per net per horse-power. In the development of a water power for long-distance transmission, the cost of electrical development remains constant so to speak ; that is, there is little opportunity for reduction in the cost of this plant. Therefore, in the construction of a water-power plant for the generation and transmission of electricity, the saving in first cost must necessarily be in the development of the water power. It, therefore, behooves the engineer, designing such a plant, to look well into the subject before recommending the plan for adoption, and submitting then only such a plan as is consistent with economic principles and with results to be obtained. In regard to the efficiency of water wheels. Under the most favorable conditions, the best wheels give 85 per cent., as stated by Mr. Farmer, but in practice I find 75 per cent. efficiency to be given for wheels under general conditions. Another loss of 25 per cent. in electrical transmission for distances up to thirty miles can be safely counted upon. I allow, in my own calculations, a loss of 50 per cent. always between the actual gross horse-power of a stream and the effectual transmitted power.

Mr. R. E. Chandler.—I should like to draw attention to the very high evaporation power which the wood, used in tests given by Mr. Farmer, must possess.

According to this table, 4.4 pounds of wood were burned per horse-power per hour. It has been usual to figure one pound of wood as equivalent to .4 of a pound of coal. On this basis, the engine would be showing an efficiency equivalent to generating a horse-power on 1.76 pounds of coal per hour.

Mr. Parker.—The cost of the development of water power at Great Falls, with a dam of an average height of 15 feet, and crest nearly 800 feet long, was $175,000. I am sure, from my own investigation of the site under discussion, that a combination crib-dam, 30 feet high, could be built for $100,000, and that the entire plant for the delivery of electricity to the amount of 3,445 horse power at a central power-house in Helena, could be constructed within the cost of a dam and other works at Stubbs' Ferry, as estimated by Mr. Farmer. I know that the cost of water power, in some of the principal States using it, is about $13.00 per horse-power. The cost for wheels for power-house is about $50.00 for the amount they use. The actual charge for power against each branch of industry is charged with the amount of power it consumes at the rate of cost. Two or three instances I have in mind—the actual cost of power is from $13.00 to $25.00 ; at Black Eagle Falls, it is $13.00 ; at Great Falls, $16.00, and at Spokane Falls, as high as $25.00.

Mr. Bickel.—Have you formed any idea what the horse-power would cost from the river here?

Mr. Parker.—Only approximately. It would cost $10.00.

Mr. Bickel.—What they could not sell here, they could sell at the river?

Mr. Parker.—Yes. There is one thing in the building of works at the river ; that is, the entire amount of power that can be generated there. The base of the dam would be built for the idea of carrying the dam 30 feet high. The dam could be built 15 feet high and a crest that can be carried up in it with a power that would warrant the money. If the dam, at 30 feet high, would have cost $100,000, then at 20 feet, it would have cost about $75,000. That leaves $25,000 there, and the

necessary wheels would only have to be set in the power-house, and be built for the size that is needed for the full amount of power as fast as it is needed for the consumers. It need be only large enough to answer the call for it. There are quite a number of items in Mr. Farmer's estimate that are very low in my opinion. For instance, the cost of masonry. There are 1,922 cubic yards in the facing, at $10.00, which would cost $13.00 per yard. 420 cubic yards, at $14.00, would probably cost $22.00. Some of the other items for coffer-dams and pumping are perhaps large enough; but the estimate for rubble masonry, as it is here mentioned, is evidently given for dry-land work rather than for water work. It sometimes costs 20 per cent. more for water work than when constructed on dry land; but that is mere guess-work.

Mr. Ryon.—There is another point that should not be overlooked. The past year, I have been keeping a record of some of the rivers in Montana, which are near Bozeman, among them the Jefferson, Madison and Gallatin rivers, the principal water-supply of the proposed plant under discussion. I notice that in the flow of these rivers about the irrigation season, there is a decided drop in each of them. Every year we are taking out water from them, and may it not be true that in ten years from now it will be very low, owing to the fact that irrigators are taking the water out?

Mr. Parker.—In that connection, I would like to state that I have a daily record kept at the Missouri River at Great Falls. The overflow of the dam at the Falls constitutes a good weir, in fact, almost a perfect weir. I find that the flow of the river has increased every year since 1890. It may drop back in the next five years, but what water is taken from the river above seems to have very little effect upon it at that point. The seasons of 1889–90 were the driest seasons that have been known for some years; so I do not think that the amount of water taken for irrigation cuts very much figure in the general flow at present.

The President.—I think your position, Mr. Parker, bears out the experience that has been had before. Water taken out of the river for that purpose, usually returns to it, lower down.

It was then ordered that a record of the papers and their discussions, and of the meeting, be printed and placed before the Board of Trustees.

The Secretary then read the following resolutions upon the resignation of Prof. J. B. Johnson, as Chairman of the Board of Managers of the Association of Engineering Societies. The resolutions were adopted, and it was ordered that a copy of them be sent to Prof. Johnson.

Resolved, That the Montana Society of Civil Engineers learns with sincere regret of the resignation of Prof. J. B. Johnson as Chairman of the Board of Managers of the Association of Engineering Societies, and appreciates the untiring zeal and deep interest which have characterized the discharge of his duties while occupying that position. It recognizes the healthy growth of the Association during his incumbency of the office, the labor of love displayed through his conscientious and successful efforts to maintain in a fitting manner the Index Department of the Journal, and his invaluable services, rendered fully and timely, to the advancement of the interests of the Association.

Resolved, By the Montana Society of Civil Engineers, that a copy of this preamble and resolution be enrolled upon our minutes and published in the Journal of the Association of Engineering Societies, and that a copy be forwarded at once to Prof. J. B. Johnson, wishing him a long life in which to continue his self-appointed task of earnest endeavors toward advancing the interest and the progress of the engineering profession.

The meeting then adjourned. F. J. Smith, *Secretary*.

Boston Society of Civil Engineers.

JANUARY 22, 1896.—A regular meeting of the Boston Society of Civil Engineers was held at its rooms, 36 Bromfield Street, Boston, at 7.40 P.M. President Albert F. Noyes in the chair. 142 members and visitors present.

The record of the last meeting was read and approved.

Messrs. Ernest W. Bailey, Wallace C. Brackett, Andrew D. Fuller and Theodore Horton were elected members, and Mr. Herbert L. Grew, an associate of the Society.

The Secretary read a memoir of Phinehas Ball, a member of the Society, prepared by Messrs. Charles A. Allen and Lucian A. Taylor.

On motion of Mr. A. H. French, the President was requested to appoint a committee of three to retire and report to the meeting the names of five members to serve as a committee to nominate officers for the ensuing year. The President appointed as this committee Messrs. French, FitzGerald and McClintock. Later in the meeting this committeee reported the names of Messrs. J. R. Freeman, A. E. Burton, Allen Hazen, G. A. Kimball and C. H. Swan, and upon motion the members named were elected a committee to nominate officers for the ensuing year.

The President stated that the Trustees of the Boston Public Library desired the Society to become responsible for the use and safe return of books loaned to those of its members who are not residents of Boston and to whom cards had been given in consequence of their membership. On motion, the Secretary was authorized to sign an agreement satisfactory to the Trustees.

The Secretary read a letter from Mr. Frank L. Locke, resigning the office of Librarian of the Society, and on motion the resignation was accepted. It was further voted that the committee to nominate officers chosen at this meeting be requested to report at the next meeting a nomination for librarian to fill the vacancy.

On motion of Mr. Wood the thanks of the Society were voted to President Eliot, of Harvard University, for courtesies shown this afternoon on the occasion of the visit to Harvard College.

The following resolution, adopted at the last meeting, was ratified by a vote of 37 in favor and 2 against:

Resolved, That the Boston Society of Civil Engineers earnestly deprecate the use of any of the wire and sheet metal, or other trade gauges now in vogue, and strongly urge the use of a *decimal system* for all such measurements.

On motion of Mr. Whitney, it was voted to hold the annual dinner at the usual time in March. It was also voted that Mr. Henry Manley be a committee to make the necessary arrangements, and that the sum of $50 be appropriated for the incidental expenses of the dinner.

Mr. Howard A. Carson then gave an informal talk, in which he described some of the interesting engineering works seen by him in his tour in Europe last spring. The talk was illustrated by a large number of lantern slides.

Adjourned.

S. E. TINKHAM, *Secretary.*

Phinehas Ball.—A Memoir.

By Charles A. Allen and Lucian A. Taylor, Committee of the Boston Society of Civil Engineers.

[Read January 22, 1896.]

Phinehas Ball, eldest son of Manasseh Sawyer and Clarissa (Andrews) Ball, was born in Boylston, Mass., January 18, 1824.

He came of Puritan stock, being descended on his mother's side from Simon and Anne Bradstreet. His father was the youngest son of Elijah Ball, a soldier of the Revolution, who was in General Putnam's retreat on Long Island and attained in 1779 the rank of first lieutenant.

Mr. Phinehas Ball began life with a frail body and his youth was a continued struggle with ill health. The seasons of close application devoted to study and teaching were followed by severe illnesses that ate up his scanty earnings. His early education was limited in the extreme, and such was his poverty that he was at times compelled to settle for his tuition by payments in charcoal and other produce.

In the winter of 1841, he taught school in Southborough; the following winter in Lancaster, and then in Marlborough.

In the fall of 1846 he began studying draughting in Worcester, but was soon prostrated with typhoid fever and unable to do any work until the following April, when he was associated with a Mr. Kirby in Worcester. In June he was employed to survey the Worcester Aqueduct, and was thus enabled to free himself from debt.

His own early struggles made him quick to sympathize with others in like difficulty, and he never failed to help them to the utmost of his ability.

In April, 1849, he became associated with Elbridge Boyden, under the firm name of Boyden & Ball, Architects and Engineers, and the partnership lasted until 1860. He planned the first sewer in Worcester, and his field books, covering a period of twenty-five years, show how closely he was identified with the growth of that city.

While engaged in general work for the city of Worcester he was concerned in the construction of the Taunton Hospital for the Insane, and the Fitchburg Jail. He became a member of the Mechanics' Association in 1853, and served as clerk from 1857 to 1865, being also treasurer for seven years of that time, and afterwards director, vice-president and president for short terms. For seventeen years he was one of the directors of the Mechanics' Savings Bank. In 1862–63 he served the city in the Common Council; in 1865 he was mayor; from 1863 to 1867 water commissioner, and from 1867 to 1872 city engineer.

With the Yankee instinct for the better or quicker method, Mr. Ball patented various devices used in connection with water works. After working for some years on a water meter, he found that Mr. Beniah Fitts had developed a like device, and the two entered into partnership, patented a meter, and in November, 1869, formed the Union Meter Company, of which Mr. Ball was made president. In 1872 he was appointed engineer in the abatement of the Miller's River nuisance.

In 1873–75 he built the Springfield Water Works, and during the same time made plans or gave advice for water works at Nashua, N. H., Amherst, Leominster,

Marlborough, Lawrence, Westborough, Fitchburg, Portland, New Haven and New Britain, and for sewers for Keene, Fall River and New Britain.

In 1876 Mr. Ball received a grievous blow in the breaking of the dam at Lynde Brook Reservoir. It was his first considerable work, and one in which he took just pride, and the disaster cut deep into his sensitive soul. He took refuge in no extenuating circumstance, but worked steadier and found relief in such work. That year he reconstructed a broken dam at Clinton.

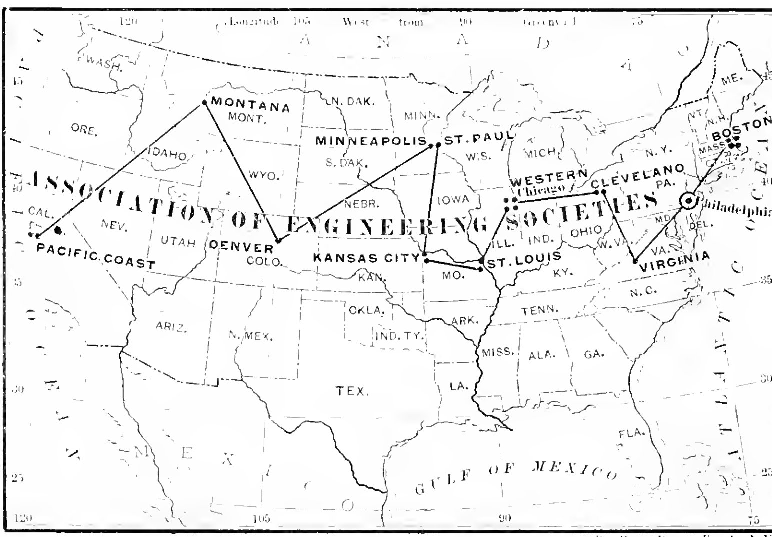
In 1879 he began the Brockton Water Works, and continued in the service of that city for a number of years, planning a system of sewers. He also planned sewerage systems for Amherst, Westborough and the Concord and Sherborn prisons and water works for Claremont, N. H., Gloucester, Mass., and additional works for Lynn, Mass., and New Haven, Conn.

In 1887 he began work on the drainage of the Mystic Valley, but the malarial air of the Saugus marsh aggravated his old troubles. He was forced to resign his position the next year, and was not able again to undertake any work of importance. But he was never idle. When forced to remain indoors, experimental chemistry was his resource, and in this study he obtained some results of practical value.

He was much interested in the formation of the Worcester County Society of Engineers, and was its president while health permitted.

In 1894 he enjoyed better health than for a number of years, but in November a little overwork and a chill brought his life rapidly to a close, and he died on the 19th of December.

On December 21, 1848, Mr. Ball married Sarah Augusta, daughter of Captain William Holyoke, of Marlborough, and two children were born to them, Allard Holyoke, who died in 1857, and Helen Augusta, still living. Mrs. Ball died in 1864, and on November 29, 1865, Mr. Ball married Mary Jane, daughter of Benjamin B. Otis, of Lancaster. Mr. Ball joined the Boston Society of Civil Engineers, October 19, 1887.



Bradley & Poates, Engr's N.Y.

ASSOCIATION
OF
ENGINEERING SOCIETIES.

VOL. XVI. FEBRUARY, 1896. No. 2.

PROCEEDINGS.

Association of Engineers of Virginia.

ANNUAL MEETING, ROANOKE, VA., JANUARY 25, 1896.—The annual meeting of the Association was called to order January 25, 1896, by the President, Mr. J. C. Rawn, who submitted the following report from the Board of Directors:

I beg to present herewith a report of the operations of this Association for the year 1895, together with such suggestions as have appeared pertinent to me.

The bad financial conditions which obtained during 1893 and 1894 had so seriously affected all interests, but most particularly such as engineers were dependent upon for a livelihood, that at the close of 1894 a large number of our members were without engagements and consequently without the financial support necessary to maintain themselves. As a result of this condition, many of our members found it impracticable to meet their obligations to this Association, and either their resignations were accepted or they were dropped from membership for delinquency. A number of our members, but particularly those residing outside of Roanoke, believed that their membership in this Association did not afford them a sufficient return in engineering literature or information. Your Board of Directors recognized the virtue of this contention, and realizing that our revenues were not sufficient to meet the expenses attendant on the publication of our papers, were considering the best means to allay any dissatisfaction and to solidify and strengthen what was remaining of the Association, the membership having decreased nearly 70 per cent., when the opportunity to become a member of the Association of Engineering Societies presented itself and was accepted, as your Board of Directors believed that by such action a solution of our difficulties would be brought about.

The results have entirely justified the action of the Board, all members being satisfied with the amount and character of the literature and the reduction in expenses and dues, so that at this time our Association is out of debt and has every promise of being able to maintain itself without financial embarassment.

It has been regretted by those who have been accustomed to be present at our regular and informal meetings that more of our members have not accepted the opportunity to present papers or to be present to join in the instructive and pleasant discussions which all who have attended have enjoyed. It is suggested that all members endeavor to attend our meetings, and contribute either papers upon engineering topics or seek information or provoke discussion by submitting, through the Secretary, questions in writing upon such subjects as may come within the scope and intent of the Association.

At the date of our last annual meeting our roll contained thirty-five active and two honorary members, to which there has been added during the past year three active members, the present membership being thirty-eight active and two honorary members.

During the year there have been held five meetings of the Board of Directors and seven meetings of the Association. Six papers have been read and five informal discussions held.

The following statement from our Treasurer's books will show our receipts, expenditures and present financial status:

RECEIPTS.

Cash on hand January 1, 1895, including $140 dues for 1895	$158 52	
Received from initiations	7 50	
Received balance of annual dues, 1895	35 00	
		$201 02

EXPENDITURES.

Paid for entrance fees and dues to Association of Engineering Societies	$127 00	
Stationery and printing	5 00	
Incidentals, postage, etc.	7 95	
Cash on hand January 1, 1896	61 07	
		$201 02

Both the Secretary and the Treasurer deserve the thanks of the Association for the careful and efficient manner in which their duties have been performed.

Respectfully,

J. C. Rawn, *President.*

The election of officers for the ensuing year was announced, and the President appointed as Scrutineers of the ballots, Messrs. C. S. Churchill, H. A. Gillis and M. E. Yeatman, who reported the following as elected:

President, D. C. Humphreys; Vice-President, G. R. Henderson (to serve two years); Secretary, John A. Pilcher; Treasurer, James Schick; Directors (to serve three years), Hermann Crueger, R. A. Marr and J. C. Rawn.

These same Scrutineers were appointed to examine the ballots on the change in Constitution and Rules, and reported as follows:

Change in Article I.—Affirmative 9; negative, 8. Article declared unchanged, since a two-thirds vote is required.

Change in Article IX.—Affirmative, 16; negative, 1. Declared to be changed, and when changed reads as follows:

Article IX—Amendments.

These rules may be amended at any annual meeting by a two-thirds vote of the members present; *provided*, that written notice of the proposed amendment shall have been given at a previous meeting; and *provided* also, that the amendment or amendments so adopted shall be printed upon a ballot and sent, not later than thirty days thereafter, to all members, and each person receiving the same shall be requested to return it to the Secretary with his written vote of YES or NO to each amendment, and his signature; and the President shall appoint as Scrutineers, three members, who shall examine all of the said ballots which shall have been returned within one month from the date of their distribution, and shall report the result; and the Secretary shall publish and distribute to members, not later than the next distribution of printed matter, an announcement of the said result so reported, together with the text of the additional or amended rule or rules so adopted; and the amendment or amendments approved by the majority of the ballots so returned and reported shall become part of these rules from and after the publication of said announcement by the Secretary.

Mr. H. A. Gillis presented to the Association a communication from Mr. L. S. Randolph, calling attention to a bill in Congress, H. R. 3618, for the purpose of increasing the efficiency of the Navy, and asking the Association to take some action in regard to it. On motion of Mr. Churchill to appoint a committee of three

to urge this matter upon the attention of the members of Congress from Virginia, the President appointed on such committee Mr. H. A. Gillis, Mr. C. S. Churchill and Mr. G. R. Henderson.

Mr. Gillis reported a road improvement bill in the Virginia Legislature, and on motion this same committee were instructed to use the influence of this Association to have it passed.

The Secretary reported that he had received, through Mr. Hurley, member of Congress, a copy of Bill H. R. 2758, "To fix the standard of weights and measures by the adoption of the metric system of weights and measures," proposed by him. After much discussion for and against the bill, the matter was on motion laid on the table.

Mr. Wm. M. Dunlap read a paper on "Assessments for Municipal Improvements," which was of much interest, pointing out that none of the simple methods in use, whether by frontage, area or valuation, would be found equitable in all cases, but recommending a combination of two or more of these. The paper brought out considerable discussion, and on motion was referred to the Publication Committee.

On motion of Mr. Yeatman the thanks of the Association were tendered Mr. J. C. Rawn, the outgoing President, for his efficient services during the year, which motion was amended so as to include in the thanks the Secretary and the Treasurer.

On motion of Mr. White the thanks of the Association were voted the Norfolk and Western Railroad for the use of their offices as a meeting place during the year.

John A. Pilcher, *Secretary.*

N. B.—Papers from members on any engineering subjects are desired. Please forward same to Secretary.

List of Officers of the Association.

President—D. C. Humphreys, Lexington, Va.; term expires January, 1897.

First Vice-President—M. E. Yeatman, Roanoke, Va.; term expires January, 1897.

Second Vice-President —G. R. Henderson, Roanoke, Va.; term expires, January, 1898.

Treasurer—James R. Schick, Roanoke, Va.; term expires January, 1897.

Secretary—John A. Pilcher, Roanoke, Va.; term expires January, 1897.

Directors—Hermann Crueger, J. C. Rawn, Roanoke, Va.; R. A. Marr, Lexington, Va.; terms expire January, 1899. C. S. Churchill, H. C. Macklin, Roanoke, Va.; L. S. Randolph, Blacksburg, Va.; terms expire January, 1898. W. W. Coe, H. A. Gillis, Wm. M. Dunlap, Roanoke, Va.; terms expire January, 1897.

Civil Engineers' Society of St. Paul.

St. Paul, Minn., February 3, 1896.—A regular meeting of the Civil Engineers' Society of St. Paul was held at 8.30 p.m.. Fourteen members and five visitors present. After the reading of a few communications requiring no action, President Stevens announced Mr. Archibald Johnson, who displayed the drawings and explained the details of the bear-trap lock gates at Sandy Lake. Lieut. W. A. Jones, U. S. Eng. Corps, followed with suggestions as to the probable application of the bear-trap weir foreshadowed by its use at Sandy Lake. Inexpensive, simple in construction, easily repaired, self-cleaning and almost self-acting, the bear-trap

gate is destined to wide application. The Sandy Lake lock has been in almost constant operation this winter, a temperature of perhaps 30° below zero not having interfered with its work. "With this form of lock, then," said Col. Jones, "might not the Great Lakes be navigated without winter interruption?"

After a short discussion, a design for a society escutcheon, to be used on stationery, etc., was presented and informally adopted.

The Librarian was instructed to procure shelving for current periodicals.

Adjourned at 10.30 P.M.

C. L. ANNAN, *Secretary.*

Engineers' Club of Minneapolis.

MINNEAPOLIS, MINN., FEBRUARY 3, 1896.—The Annual Meeting of the Engineers' Club of Minneapolis was held at 8 o'clock P.M., at the office of the City Engineer, City Hall. Vice-President I. E. Howe in the chair.

The minutes of the previous meeting were read and approved.

The reports of the Secretary, the Treasurer and the Librarian were read and accepted.

Election of officers was postponed to the next meeting.

Mr. G. D. Shepardson was elected as representative of the Club on the Board of Managers of the Association of Engineering Societies.

The future of the Club was informally discussed.

The meeting adjourned to meet on the first Monday in March (2d proximo), which meeting was by motion made a regular meeting for the election of officers. Papers by W. W. Redfield on "Triangulation for the Location of a Tunnel for the Discharge Pipes of the East Side Pumping Station;" by W. R. Hoag, on "Precise Level Benchmarks;" and by A. B. Coe on "Measurements of a Difficult Base Line," were promised for this meeting.

ELBERT NEXEN, *Secretary.*

Engineers' Club of St. Louis.

430TH MEETING, FEBRUARY 5th, 1896.—President Ockerson called the Club to order at 8.30 P.M., at 1600 Lucas Place, with thirty members and five visitors present. The minutes of the 429th meeting were read and approved. The Executive Committee reported the doings of its 207th meeting with the following program of papers for the year:

January 8th—English Railway Practice, Geo. B. Leighton.
January 22d—Underground Electrical Service, E. J. Spencer.
February 5th—Engineering Materials in Compression, J. B. Johnson.
February 19th—An Instrument for Testing Gauges to 500 Pounds, J. H. Kinealy.
March 4th—A New Design for a Stadia Board, O. W. Ferguson.
March 18th—The Testing of Coals, Arthur Winslow.
April 1st—Municipal Engineering, Sub-divisions and Grades, Julius Pitzman.
April 15th—The Maintenance of Bridges, Carl Gayler.
May 6th—The Construction of a Low Crib Dam Across Rock River, J. W. Woermann.
May 20th—A New Cross-Breaking Testing Machine, Malverd A. Howe.
June 3d—Fly Wheels, Herbert A. Wagner.
September 16th—The Galveston Harbor Improvements, W. J. Sherman.

October 7th—Some Notes on the Operation of the St. Louis Water Works Conduit, S. Bent Russell.

October 21—Boiler Efficiency with Low-grade Fuels, William H. Bryan.

November 4th—Steel Frame Construction of High Buildings, Julius Baier.

November 18th—Dredging the Mississippi River, Edward Flad.

December 2d—Annual Meeting, Reports of Officers and Committees.

December 16th—Annual Dinner, Installation of Officers, Address of Retiring President.

The Executive Committee reported with their approval applications for membership from W. G. Comber, Horace Dunaway, and J. L. Van Ornum. They were balloted for and elected. An application for membership was announced from O. H. B. Turner, Civil Engineer with Missouri River Commission.

Prof. J. B. Johnson then addressed the Club on the subject of "Engineering Materials in Compressive Stress." He explained the development of a formula for the compressive strength of a brittle solid, which was shown to be borne out by experiments. He also gave empirical laws for the relative crushing strength of prisms of various relative heights, and for loads on portions of the upper surface. Also strain diagrams for compressive tests on stone and brick masonry, and concrete. The formula in question was originally developed by Mr. Charles Bouton, a fifth-year student at Washington University, and was thought to be original, but was found later to have been arrived at at an earlier date by a German engineer. The paper was illustrated by numerous charts, diagrams, and by photographs thrown upon the screen.

The discussion was participated in by Messrs. Baier, Kinealy, Harrington, Flad, Olshausen and Barth. Adjourned.

William H. Bryan, *Secretary.*

431st Meeting, February 19, 1896.—The Club was called to order at 8.30 p.m. by President Ockerson, at 1600 Lucas Place. Sixteen members and three visitors present. The minutes of the 430th meeting were read and approved. The Executive Committee reported doings of its 208th and 209th meetings, approving the Treasurer's accounts for 1895, and approving the application for membership of O. H. B. Turner. He was balloted for and elected. The resignation of A. M. Lockett was announced.

On motion of Mr. Crosby the Secretary was directed to request the Committee on Library to prepare rules to govern the use of periodicals and books outside of the Club rooms.

Prof. J. H. Kinealy then addressed the Club on the subject of testing pressure gauges to high pressures, explaining in detail the investigations and experiments which he had recently conducted. The pressures were beyond the reach of the ordinary mercury column and special apparatus was therefore necessary. The plan which he had developed consisted in measuring the reduction in volume of an air column which was maintained at constant temperature. The volume decreased exactly as the pressures increased. He had in this way measured pressures up to 675 pounds per square inch.

Messrs. Barth, Freeman, Flad, Ockerson, Crosby, Harrington and Prindle took part in the discussion.

It was thought that the increase of temperature due to compressing the air, the possible absorption of air by the water, and the possible expansion of the tube itself under the increase of pressure, might introduce errors. Prof. Kinealy thought, however, that they were not sufficiently large to vitiate the results.

Mr. Barth showed the Club some curious pieces of steam engine piston packing rings which had evidently gone through a severe experience.

Adjourned.

William H. Bryan, *Secretary*.

Technical Society of the Pacific Coast.

Regular Meeting, held February 7, 1896.—Called to order by President Dickie at 8.30 p.m.

Minutes of January 3d and 17th approved.

After substituting the name of Prof. C. B. Wing for Albert T. Smith on the Timber Committee, John Cotter Pelton was declared duly elected member of the Society.

Propositions for membership were read as follows: Fred W. Wood, Los Angeles, Cal., endorsed by A. M. Hunt, W. F. C. Hasson and Hubert Vischer; Lou G. Hare, Salinas, Monterey Co., Cal., endorsed by Adolph Lietz, per O. v. G., Otto von Geldern and Hubert Vischer.

The absence of Mr. Isaacs from the meeting was explained by letter from Mr. W. G. Curtis, Mr. Isaacs being in Oregon on professional business.

President G. W. Dickie delivered an address upon reassuming the presidency of the Society.

In the absence of Mr. Isaacs, the Acting Secretary was requested to read the paper of the evening, with the view of at least making the members familiar with the subject, which is to be again taken up when Mr. Isaacs is present.

On motion, the discussion of the paper was postponed to the next regular meeting, in order to have Mr. Isaacs present.

Discussion on general lines, particularly with reference to handling materials with grab-buckets, participated in by Mr. Richards, Mr. Wagoner, Prof. Wing, Prof. Soulé and President Dickie.

C. E. Grunsky, *Acting Secretary*.

Civil Engineers' Club of Cleveland.

Meeting of the Civil Engineers' Club of Cleveland, February 11, 1896, at the Rooms, Case Library.

Meeting called to order by the Secretary at about 8 p.m. Mr. Ambrose Swasey was invited to preside. The President afterwards came in and took the chair. Present fifty-three members and visitors. The minutes of the last meeting and the report of the Executive Board were read and approved.

The Committee on Resolutions, regarding the death of General M. D. Leggett, offered the following, through Mr. C. H. Strong, Messrs. Barnett and Holden being absent from the city:

" *Resolved*, that we, the Members of the Civil Engineers' Club of Cleveland, learning with sorrow of the death of our brother member, General M. D. Leggett, desire to express our appreciation of his sterling character, of his worth to our country, our city and to our Club, and of our sense of great loss in his death.

" He was one of the early members of the Club, being elected at the first regular meeting, April 3, 1880.

" We have the pleasure of the memory of his late presence with us and of his

voice in our meetings. We are proud of the honor of possessing his name for so many years upon our rolls.

"We extend to his bereaved family our sincere sympathy."

The resolutions were ordered spread upon the minutes and sent to the family of Mr. Leggett.

The death of Mr. Geo. M. Reid was announced, and Mr. Mordecai read a letter from Mr. E. A. Handy, Chief Engineer of the L. S. & M. S. R. R., testifying to the ability and integrity and worth of Mr. Reid.

The following committee was appointed to draft suitable resolutions: Messrs. E. A. Handy, C. A. Carpenter, A. H. Porter, Jno. L. Culley and James McIntyre.

It was decided that the members of the Club meet at the School House, corner of Central and Case Avenues, and attend the funeral together on Thursday afternoon.

The Committee on the Nomination of Officers for the ensuing year reported as follows:

For President, Chas. S. Howe.
" Vice-President, James Ritchie.
" Secretary, Forrest A. Coburn.
" Treasurer, James C. Wallace.
" Librarian, A. Lincoln Hyde.
" 1st Director, Jno. L. Culley.
" 2d Director, Jos. C. Beardsley.

Messrs. S. J. Baker and D. C. Miller were appointed tellers to canvass the votes for the change in the Constitution, as follows:

Article V, Section 1.—Dues. Strike out "ten" and substitute "five."

They reported later that there were twenty-six votes for and eight against, and the amendment was reported carried.

The President invited the Club to meet at his office in the Garfield Building on Wednesday evening, and proceed together to the Architectural Exhibition on the floor below.

Mr. Rice, the speaker of the evening, then gave an account of the cracking of a large cast iron pipe culvert, and of the settlement of the piers of the Central Viaduct, and the method employed in raising them.

Messrs. Force, Searles, Thompson and others contributed accounts of the failure of various engineering works, and the unreliability of the silt formation of the Cuyahoga Valley was generally testified to.

Owing to the lateness of the hour and to the fact that the lunch was awaiting the Club, the discussion of the Metric System was deferred to a special meeting to be held on February 25, 1896.

Dr. Dayton C. Miller had on exhibition some of the Case School's interesting standards and weights and measures of the Metric System.

F. A. Coburn, *Secretary.*

Bradley & Poates, Engr's, N.Y.

Association of Engineering Societies.

Vol. XVI. | March, 1896. | No. 3.

PROCEEDINGS.

Boston Society of Civil Engineers.

February 19, 1896.—A regular meeting of the Society was held at its rooms, 36 Bromfield Street, Boston, at 7.45 p.m., President Albert F. Noyes in the chair. Sixty members and visitors present.

The record of the last meeting was read and approved.

Messrs. James M. Betton, Edwin F. Dwelley, Walter I. Johnson, Hiram A. Miller, John W. Morrison and Sturgis H. Thorndike were elected members of the Society.

The President reported for the Board of Government a recommendation that the annual dues of the Society be increased one dollar, and in accordance with this recommendation notice was given in writing, that the first clause of By-law 10 be amended so that it shall read:

The entrance fee shall be ten dollars. The annual dues shall be eight dollars for members and associates residing within thirty miles of Boston, and five dollars for those residing at a greater distance, payable in advance at the annual meeting. Members elected after September 1st shall pay but one-half the annual dues for that year.

The President read a communication from the Board of Government recommending that George L. Vose be made an honorary member.

The Committee to nominate a candidate for Librarian to fill the vacancy caused by the resignation of Frank L. Locke, reported the name of Alfred D. Flinn, and upon a ballot being taken, he was elected unanimously.

On motion of Mr. Manley the sum of $25.00 was added to the appropriation for the incidental expenses of the annual dinner.

On motion of Mr. Fuller the thanks of the Society were voted to Mr. J. H. Millet, President of the Crosby Steam Gauge and Valve Co., of Boston, for courtesies shown members of the Society on the occasion of the visit to the works of the company this afternoon.

The President appointed Messrs. William B. Fuller and Charles E. Putnam, the tellers to canvass ballots for officers at the annual meeting.

Dr. Theobald Smith, Pathologist of the Massachusetts State Board of Health, was then introduced and gave a very interesting address on the Production of Diptheria Antitoxin.

After passing a vote of thanks to Dr. Smith for his instructive address the Society adjourned.

S. E. Tinkham, *Secretary.*

February 26, 1896.—A special meeting of the Society was held at its rooms, 36 Bromfield Street, Boston, at 8 o'clock p.m., Mr. Henry Manley in the chair. 135 members and visitors present, including ladies.

Prof. Ira N. Hollis gave a very entertaining address, entitled "The Growth of our Modern Navy." At the conclusion of the lecture, Prof. Hollis exhibited and explained a series of about seventy-five lantern slides, showing some of the old wooden vessels of the navy and many of the newer war vessels.

Adjourned.

S. E. Tinkham, *Secretary.*

Civil Engineers' Society of St. Paul.

St. Paul, Minn., March 2, 1896.—Regular meeting of the Civil Engineers' Society of St. Paul, held at 8.30 p.m. Eleven members and two visitors present. President Stevens presided. The Secretary was instructed to accept the Journal of the Western Society of Engineers, and express the thanks of the Society to Mrs. Helen J. McCaine, public librarian, for suggestion as to books. The first vote on amendments to Articles IX and XX of the constitution was unanimously in favor.

A communication from the President of the Western Society of Engineers resulted in the passage of the following resolutions:—

Whereas, a bill known as House Bill No. 1470, dated December 12, 1895, introduced by the Hon. J. Frank Aldrich, M.C., in the first session of the 54th Congress, provides for the appointment of a Commission of Public Architecture to have control of the design and construction of public buildings, and further provides that said commission shall be constituted of three architects and two officers of the United States Army, and

Whereas, the problems entering into the construction of large buildings as to foundations, metal superstructure, heating and drainage, are specifically engineering ones, and are of prime importance, calling for a high grade of engineering ability, therefore, be it resolved by the Civil Engineers' Society of St. Paul, Minnesota, that the Hon. J. F. Aldrich be respectfully requested to so amend House Bill No. 1470 as to provide for the appointment of at least one Civilian Civil Engineer as a member of said Commission of Public Architecture.

Resolved, that our Secretary be directed to forward these resolutions to the Hon. J. F. Aldrich and to the Senators and Representatives from Minnesota.

H. E. Clark and Robert Elden were elected to membership.

Mr. K. E. Hilgard presented some notes on the use of structural steel in railroad rolling stock. Having been employed for some months in applying the principles of bridge engineering to the car trucks of the N. P. R. R. system, with intent to reduce weight, increase strength, simplify parts and debar cast iron and wood, his discourse, fully illustrated by detail drawings, was novel and entertaining.

Mr. Hilgard calculates that the saving in the weight of a car truck amounts to a cent and a half per pound per annum.

Adjourned at 10.30 p.m.

C. L. Annan, *Secretary.*

Engineers' Club of Minneapolis.

MINNEAPOLIS, MINN., MARCH 2, 1896.—A regular meeting of the Engineers' Club of Minneapolis, for the election af officers, was held at the office of the City Engineer at 8 o'clock P.M. The President, F. W. Cappelen, in the chair.

Minutes of previous meeting were read and approved.

Letters from John F. Wallace, President of the Western Society of Engineers, enclosing one from Hon. J. Frank Aldrich, M.C., asking to have House Bill 1470 amended by adding civil engineers to the Commission of Public Architecture, were read, and after discussion a motion was unanimously adopted that it was the sense of the meeting that civil engineers should be represented upon the Commission, and our President was directed to write our members of Congress urging them to have the bill so amended.

The following officers of our Club were then elected for 1896:

President, F. W. Cappelen.
Vice-President, I. E. Howe.
Secretary and Treasurer, Elbert Nexsen.
Librarian, A. B. Coe.

W. W. Redfield then read a paper on "Triangulation for Location of Tunnel for Discharge Pipes at East Side Pumping Station."

After informal discussion, this was followed by a short paper by W. R. Hoag, on "Precise Level Benchmarks," illustrated by samples of brass balls, which he has used in this vicinity, and which are inserted in the vertical walls of permanent structures; they are so made that even after their removal from the structure a very close approximation can be made of the original line of the benchmark which has been destroyed.

It was then moved and carried that the reading of A. B. Coe's paper on "Measurement of a Base-line Under Difficulties," be postponed to the next meeting. A paper was also promised by E. H. Loe on "Flour Mill Construction" for that meeting.

The name of F. H. Constant was proposed for membership by W. R. Hoag.

On motion, adjourned.

ELBERT NEXSEN, *Secretary.*

Engineers' Club of St. Louis.

432D MEETING, MARCH 4, 1896.—The Club met at 1600 Lucas Place, at 8.45 P.M., President Ockerson in the chair. Eighteen members and two visitors present.

The minutes of the 431st meeting were read and approved. The Executive Committee reported the doings of its 210th meeting. Mr. Julius Baier, chairman of the Committee on Library, reported the following rules:

(1) All new books and periodicals shall be kept on the table for one month and shall then be filed.

(2) No book or periodical shall be taken from the Club rooms within one month of its receipt.

(3) No book shall be kept out longer than one month. At the end of that time it must be returned, but may be taken out again, if there is no call for it on record.

(4) Any member taking books from the Club rooms must enter same with date of issue and return against his name in the record book.

(5) Members wishing any book which is out, may place a request on file in a record kept for that purpose, and shall be entitled to the book in the order of the names on the record.

Each of these rules was considered, and voted upon separately, and all were adopted as proposed with the exception of the third, which was amended by the substitution of the word "week" for the word "month."

The paper of the evening, by Mr. O. W. Ferguson, on "A New Design for and Method of Reading a Stadia Board," was read in Mr. Ferguson's absence by Mr. F. B. Maltby. The paper was accompanied by blue prints showing the proposed marking of rod. The author explained the difficulties he had met with, and gave reasons for the remedies proposed. Messrs. F. B. Maltby and W. G. Comber submitted written discussions. The others participating in the discussion were Messrs. Turner, Van Ornum, Jolley and Ockerson.

Attention was called to the fact that the system proposed was not new, but had been tried years ago. Reasons were given why it had not proved desirable in practice and had been discarded. Adjourned.

William H. Bryan, *Secretary.*

433d Meeting, March 18, 1896.—The club was called to order at 8.20 p.m., by President Ockerson, twenty-four members and two visitors present. The minutes of the 432d meeting were read and approved. The executive committee reported the doings of its 211th meeting, recommending that the club endorse the action of the president in writing to certain members of Congress urging that the civil engineering profession be represented on the commission on public architecture, under bill No. 1470, now being considered. On motion of Mr. Russell the Club ratified the action of the president.

Mr. Arthur Winslow then read a paper on "The Testing of Coals," being a consideration of the methods and objects involved in determining the properties and relative values of different coals for all uses, with special references to a series of investigations now in progress by the author He classified the most important uses of coal as follows: first, steam making; second, coking; third, domestic fires; fourth, gas making; fifth, forge and blacksmith work.

Mr. Winslow's plans contemplate the investigation of all the standard coals of this country, with a view to determining their relative values for the above uses. The methods he proposes to adopt are as follows: first, inspection at the mines; second, collection of samples; third, proximate analyses; fourth, calorific determinations; fifth, laboratory tests; sixth, study of the coal in actual service.

Further investigations in other and special directions will be undertaken as the work develops and necessity demands. Work in the field has already begun, and the investigation will probably extend over a number of years. The author expects to make progress reports from time to time as portions of the work are completed, and he will probably collect all the results in a single publication when the work is completed.

Discussion followed by Messrs. Moore, Meier, Kinealy, Leighton, Bryan, Flad and Russell. The value of calorimeter tests was discussed, as well as the various methods of making such tests.

President Ockerson gave the results of some capacity tests on the new United States dredging boat "Beta," now operating near Memphis.

Col. Meier explained a bill now before Congress looking to the improvement of the standing of naval engineers, and asked the members present to join him in signing a petition to St. Louis Congressmen, commending the subject to their favorable consideration. Adjourned. WILLIAM H. BRYAN, *Secretary.*

Technical Society of the Pacific Coast.

REGULAR MEETING, MARCH 6, 1896.—Meeting called to order by Vice-President Curtis. Minutes of the regular meeting of February 7, 1896, read and approved.

The following gentlemen were elected to membership by regular ballot: Lou G. Hare, of Salinas, Monterey Co., and Fred W. Wood, of Los Angeles.

Propositions for membership were read as follows: F. S. Edinger, of Berkeley, Cal., endorsed by J. H. Wallace, W. G. Curtis and John D. Isaacs; W. S. Keyes, of San Francisco, proposed by Ross E. Browne, H. C. Behr and Hubert Vischer.

A communication from J. F. Wallace, President of the Western Society of Engineers, Chicago, with enclosure referring to the proposed action by Congress looking to the appointment of a Commission consisting of three architects and two army officers to serve as a Commission of Architecture, and calling attention to the importance of having an engineer on this Commission, was read. The enclosure was a letter to the author of the bill, Hon. J. Frank Aldrich, M.C., Washington, D. C., calling attention to the importance of the engineer's work in modern architecture, and asking for an amendment to the bill (now on its third reading) as above indicated.

Moved by Mr. J. H. Wallace, and duly seconded, that the Secretary be directed to draft a letter substantially on the lines of the letter of Mr. J. F. Wallace, to be addressed to the Hon. J. Frank Aldrich, M.C., Washington, D. C. (and send copy of same to Mr. Wallace, President of the Western Society of Engineers).

Thereupon followed a discussion of Mr. Isaacs' paper on "Modern Coal-handling Machinery," participated in by Mr. Isaacs, John Richards, Prof. Wing, G. W. Percy, Prof. Soulé and Randell Hunt.

Mr. John Richards read a very interesting paper on "Standard Measures," based on a lecture recently delivered by him before the students of the Leland Stanford, Jr. University.

The discussion of this paper was participated in by Prof. Smith, Prof. Soulé, Mr. Percy, Mr. Richards and Vice-President Curtis. Adjourned.

C. E. GRUNSKY, *Acting Secretary.*

Montana Society of Civil Engineers, Helena, Mont.

AT the regular monthly meeting of the Montana Society of Civil Engineers, held in the Board of Trade Rooms Saturday evening, March 14th, the following members were present: Messrs. Cumming, Relf, Keerl, Mumbrue, Taylor and F. J. Smith. The meeting was called to order by Second Vice-President A. E. Cumming.

The applications for membership of John W. Young, of Helena, and John French, of Great Falls, were read and approved, and the Secretary was directed to

send out letter ballots to be canvassed at the April meeting. The ballots for membership were canvassed, and Prof. Frederick C. Scheuch, of Missoula, and Albert J. Seligman, of Helena, were elected members of the Society.

The Chairman appointed James S. Keerl, F. J. Smith and C. W. Goodale as members of a committee upon what is known as the Architects' Bill now pending in the national legislature. The object of this bill is the appointment of five persons as a permanent commission on the design and construction of all public buildings. As the design of modern public buildings involves so many engineering problems, the above committee was appointed to endeavor to secure the proper recognition of the engineering profession upon this commission.

The Secretary read a flattering letter from Prof. J. B. Johnson, ex-President of the Association of Engineering Societies, which read in part as follows: "My somewhat intimate relations with the several societies in the Association have led me to believe that your Society is probably doing a greater work in proportion to its membership than any other society in the Association. I therefore congratulate you on the earnest and helpful policy pervading your Society."

A letter was also read from Col. J. F. Dodge, formerly President of the Society and a civil engineer who had much to do with the first location and construction of railways in this State. He said, among other things: "Please convey to the Society my heartiest greetings and my wishes for its prosperity and the maintenance of the high position in public estimation to which most useful and worthy service entitles it."

Prof. Ryon, of the College of Agriculture and Mechanic Arts, at Bozeman, sent the following letter:

"You will be pleased to learn that the action of the Montana Society of Civil Engineers in advocating proper methods for the measurement of water is now bearing fruit. The agitation of the subject attracted general attention, as might be expected. This active movement on the part of the Society was followed by the publication of our agricultural experiment station bulletin No. 6. You are, of course, aware that considerable opposition was encountered owing to the impossibility of conveying to the public a clear conception of the subject, and that naturally the conservatism of the people defeated the adoption of the measure recommended by the Society—namely, the embodying in our statutes proper laws regulating the measurement of water. Fears were also expressed at the time that the Society had some ulterior designs in the matter, it being difficult for the average mind to conceive of a professional association striving simply for the good of the State without having an axe to grind at the same time. It is therefore with pleasure that I communicate to you the news that the officers of the Farmers' Canal have informed me that they are now satisfied that for economy of installation and for general satisfaction in the results obtained the weir offers every advantage over the statutory inch box, and that they therefore propose immediately to install measuring weirs throughout their system of laterals. As this canal carries 9,000 inches we will have an object lesson which cannot fail to impress all practical men, who look into the matter, with the superiority of this method for the measurement of water; further it will appear that the Montana Society of Engineers has no interest other than the welfare of the State in the matter. The Farmers' Canal Company is one of the most successful organizations of its kind in the State, and this progressive action certainly reflects great credit on its officers."

The letter was gratifying to the members present at the meeting, as it marked the beginning of a new era in the measurement of water in this State. The adoption of the weir measurement of water by such practical men as compose the Farmers' Canal Company is assurance that at no distant date this method of measuring water will be adopted by practical men all over the State, and that the "miner's inch," which means nothing, will be wiped from the Montana statutes.

F. J. Smith, *Secretary.*

ASSOCIATION
OF
ENGINEERING SOCIETIES.

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PROCEEDINGS.

Civil Engineers' Society of St. Paul.

ST. PAUL, MINN., MARCH 6, 1896.—A regular meeting of the Civil Engineers' Society of St. Paul was held at 8.30 P.M. Fourteen members and two visitors in attendance. President Stevens in the chair. Minutes of previous meeting were read and approved.

The Constitution of the Society was amended as follows: "To inquire into delinquent dues and assessments" was added after the word "purposes" in Article IX.

Article XX was amended to read: "Any member who does not pay his assessments or dues within a period of one year shall cease to be a member unless the Government, for cause believed by it sufficient, extend the time for payment or accommodate the charges in a manner that it may consider reasonable. The Government shall hold one meeting between the first and fifteenth days of December of each year, and at such other times as the President may select, for the consideration of delinquent accounts."

The By-laws were amended by striking out Section 5 and renumbering Sections 6 to 11 inclusive to read Sec. 5, Sec. 6, Sec. 7, Sec. 8, Sec. 9, Sec. 10.

Mr. Tracy Lyon talked for an hour to good purpose on "The Maintenance of Railway Rolling Stock."

After a short discussion the meeting adjourned at 10.30 P M.

C. L. ANNAN, *Secretary*.

The Civil Engineers' Club of Cleveland.

ANNUAL MEETING, held March 10, 1896.—President Mordecai in the chair. Present 49 members and visitors. The minutes of the last regular meeting were read, and, after the addition of the article of the constitution as amended, they were adopted.

The minutes of the meeting held February 25th, for the discussion of the metric system, were also read and adopted. The report of the Executive Board, and the applications for membership of Messrs. Green and Sample, were read.

The report of the Committee on Resolutions concerning the death of Mr. Geo. M. Reid was offered and adopted, and ordered spread upon the minutes. The report is as follows:

Resolved: That we, the members of the Civil Engineers' Club of Cleveland have learned with sorrow of the death of our brother, George M. Reid.

Mr. Reid was one of the earliest members of the Club and always took an earnest and active interest in its welfare, and we feel that in his death our Club has sustained a severe loss.

We hereby extend to his bereaved family our most sincere sympathy.

Mr. Swasey and Mr. Benjamin reported progress for the Banquet Committee.

Messrs. Herman and Jewett were appointed as tellers to canvass ballots for the election of officers.

The Treasurer's report was read by Mr. Wallace, as follows:

I herewith submit the report of the Treasurer, for the year starting March 9, 1895, and ending March 10, 1896. There was a balance left from last year of $224 94. There has been collected during the year, dues, $1,234.18, and a percentage of the Cleveland Frog and Crossing Co.'s advertisements in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES of $72, making a total for the year of $1,531.12.

Disbursements for this period have been: Rent to Case Library, $75; 135 membership tickets in Case Library at $1 each, $135; Association of Engineering Societies, $651.78 of which amount $120.78 was extra assessments for the year 1894, the balance was the second, third and fourth quarterly assessments for 1896; decorations of the Club room, $126.03; invoices of caterers for lunches after meetings, $73.70; stationery, printing, stamps, etc., $287.78; leaving the total amount disbursed during the year of $1,349.39. This amount deducted from the receipts of $1,531.12, leaves a balance in the treasury of $181.83.

The permanent fund deposit, with the Society for Savings, last year was $338.30, to which has been added for the current year the sum of $65 from entrance fees, and $14.40 from interest, making a total of $79.40 that has been collected to the credit of the permanent fund this year, that added to the balance of last year, of $338.70, leave as balance of $417.70 for the permanent fund.

There has been collected for the Library fund the sum of $210, which is intact, there having been no disbursements from the same as yet.

There are about 28 or 30 members that have not paid their dues for the past year, which, if paid in, with the balance we have on hand, would leave a very nice working balance.

It was moved and carried, that after being properly audited, the report be accepted and placed on the minutes of the Club and published.

The Secretary's report was read, as follows:

The Club now numbers 164 members: engineers, teachers, business men and architects. There are:—

Honorary members	5
Corresponding members	15
Associate members	13
Active members	131

During the year 2 members have changed their names from the active to the corresponding membership roll; 4 persons have been elected to active membership and 1 to associate membership; 14 names have been dropped from the rolls

for the non-payment of the dues of 1894, as called for by the constitution; and 6 have resigned.

And with sorrow do we remember that 3 brother engineers, Mr. A. M. Wellington (formerly a member), General M. D. Leggett, and Mr. Geo. M. Reid, active members, have died.

We have 17 less in number than at the beginning of the year. Last year there was a decrease of 7 only.

It seems as though this slight falling off in membership of the past two years, the only years in which the Club has not gained in numbers, is due chiefly to the hard times and the increase in initiation fees, which have together adversely affected the income of the engineer.

The change in the constitution which was adopted at the last meeting will help, and we hope the coming year will set this matter right, and we will again resume our normal condition of increase.

As for the interest in the Club as shown by the attendance at our meetings, we have had altogether the largest since the Club was organized, the average being $48\frac{1}{6}$.

The labors of the Program Committee have this year resulted in great success. The program made out in the beginning so as to be printed in the yearly register has been followed with but few changes. The topics were of great interest and wide variety, and each meeting has been fine in its way.

Dr. Howe opened the season, April 9th, with his fine exhibition of transits with solar attachments.

Dr. Miller followed, May 14th, in the best attended meeting of the year, with his brilliant exhibition of the polariscope.

Mr. Aborn, of the Cleveland Public Schools, continued, June 11th, with his horse-sense advocacy of free-hand drawing.

Prof. Searles, July 9th, took us over our heads, into the mathematics of a flexible ring, and Prof. Benjamin back into the history of pre-historic man, his weapons and tools and their subsequent development.

Architect Barnum, September 10th, favored us with an æsthetic talk upon Educational Architecture, and October 8th, Dr. Langley gave us the latest facts and figures about the electrical production of chlorine and the disinfection of sewage.

November 12th, Engineer Osborn's solid paper upon solid floor construction for bridges was delivered and discussed.

December 10th, we made the first departure from the program in listening to the complete paper of Mr. De Laval upon the Fly-wheel Pumping Engine.

January 14th, Mr. Walter Miller gave us facts and figures about the latest developments of lake marine engines.

February 15th, Mr. Walter Rice, under the head of "Some Experiences in an Engineer's Practice," gave us some idea of the unreliability of the soil in this Cuyahoga Valley to carry weight.

The last meeting, February 25th, the only semi-monthly meeting, was devoted to the discussion of the metric system of weights and measures.

Dr. Miller's exhaustive exhibit of the workings and the merits of the system was *the talk* of the evening. Everyone was surprised at the progress already made and the advancement in public opinion in this matter. The Club passed resolutions approving the adoption of the system in this country.

The light lunches served at the close of meetings lately have been very pleasant. Their cost for all members of the Club, amounting to less than fifty cents for six lunches, is not a burden, and the opportunity for a jolly good visit together is well worth it.

There have been three excursions during the year: One to Case School, May, 14th, which was remarkable for the amount of rain that fell during the hours of its session; twenty persons present; one July 12th, the picnic to Chippewa Lake, remarkable for the number and value of the prizes awarded for athletic and other events; and one to the Johnson plant, at Lorain, fifty-five members attending. These excursions were also all remarkable for the number of ladies present.

The thanks of the Secretary are due to Prof. Searles for assistance in preparing the index to the constitution; to Mr. Osborn, the previous Secretary, for instructions and initiation into the duties of this office; and to the President for his uniform kindness and attention.

For all of these favors, and for the uniform courtesy and consideration from all the members of the Club, he is truly grateful.

The report was adopted and ordered spread upon the minutes.

Prof. Chas. H. Benjamin, Chairman of the Committee on Program for the past year, introduced his associates, who reported as follows:

Dr. John W. Langley, on Electrical Engineering, reported as follows:

The year has not produced anything startling in the line of electrical engineering, but we have had steady progress on all lines, notably in the lines of electrical railroading. I might note the completion of the great electric engine in the city of Baltimore, also an electrically propelled railroad train, at an average speed of eighty miles an hour, and a contract for the building of several electric locomotives. One marked feature of the year is that the storage battery seems to be returned to favor. It received a black eye here in America some years ago, but it is vindicating itself. It has been used in Europe to carry the heavy loads of the lighting stations. We have, in America, two installations of the storage battery for this purpose, the largest of these is the Edison plant, at New York. That installation is, said to be working very successfully, and represents a saving on the plant of about $50,000, as well as a saving in current expenses. The other installation is at Lawrence, Mass. There seems to be no reasonable doubt that the storage battery is to be used for the peak of the load during the heavy lighting between the hours of 4 and 7 in the afternoon. Two important electro-chemical installations have been made in Niagara, one of which is an establishment for the production of aluminum. The Pittsburg Reduction Company was the first customer of the Niagara Company. They have now a contract with them for 4500 H. P. to be delivered incessantly, that is twenty-four hours a day and 365 days in a year.

Closely parallel with this is the installation of the Carborundum Company, moving from Monongahela City, Pennsylvania, to Niagara. Their product is a carbide of silicon made by heating sand and coke in an electric furnace. At a very high temperature the carbon in the coke unites with the silica, setting free the oxygen and combining with the silicon. It is also said that plants for the production of carbide of calcium will be erected at Niagara shortly. In these plants lime is substituted for sand, producing a carbide of calcium. At present this carbide is restricted to the manufacture of the new acetylene, and the commercial outcome of this product is still doubtful. This carbide has not been produced at a lower price than $15.00 a ton, and apparently it cannot be produced commercially for that figure. This would make the acetylene at least $15.00 per 10,000 feet.

Another extremely interesting electro-chemical process is about to be located in Niagara: the invention of H. Y. Castner, an English-American inventor, who has turned his inventive knowledge to a new method of producing caustic soda. Many attempts have been made to manufacture soda from common salt and elec-

tricity. There has never before been known any way to prevent the chlorine, after it is liberated, from combining with the caustic soda at the other end.

Then followed illustrations upon the board.

Mr. J. N. RICHARDSON, on Architecture, reported as follows:—

Nothing of great importance has been done last year in architecture. The tall building is still with us, the latest being the St. Paul Building, in New York City, twenty-five stories high. In Boston the people have legislated the tall building not out of existence, but to a certain quarter of the city. New York is trying to limit the height of buildings proportionately to the width of the street.

There is one type of building coming into vogue, I mean the power building for light manufacturing purposes. Electrical transmission of power has brought about a great change in this type of building. We have a sample on St. Clair Street. It is well lighted and equipped with wire transmission. We are going to have power buildings up town instead of down on the flats where they now are.

MR. CHAS. S. HOWE, on Applied Science, reported as follows:—

The subject of applied science in its progress during the past year is very broad. I have selected the subject of the new Roentgen rays, or X rays, for my topic. Notwithstanding so many scientists have been at work, nothing new has been discovered. Prof. Roentgen gives the facts. This discovery is full of interest not only to scientists, but also to the common people. It is interesting to scientists because it gives a ray entirely different from anything that has been known before, and to the world at large because those rays pass through opaque substances. Light is a sensation produced by the multitude of waves in the ether which fills all space. These waves are most of them very small, and the light waves are only about on the average $\frac{1}{50000}$ of an inch in length, and four hundred millions of millions to seven hundred millions of millions pass every second. The shorter rays are called the violet end and the longer rays the red end of the spectrum. These produce the effect of light by which we see. Heat and electric rays will pass through substances totally opaque to light. Electric rays will pass through many substances that light cannot pass through. An electric wave is a very long wave, whereas a light ray is short. So the question of passing through substances opaque to light is not new to the scientific world.

Roentgen, in his article, stated that while he was at work with a Crooks tube covered with black paper, he found that by holding a sheet of paper covered with a fluorescent material, the rays of the tube passed through the air and affected the fluorescent material at some distance. He then held some opaque substance between the tube and the fluorescent paper, and it was still fluorescent. He then put a book of 1,000 pages between, and the rays passed through. Then he held his hand between the tube and the fluorescent material, and obtained a shadow of the bones in the hand upon this fluorescent material. Then he placed a photographic plate in the holder covered with a slide, where he had formerly had the fluorescent material, and put some substances between the tube and the plate, and after a certain length of exposure the shadow of the picture was developed. He found that those rays could not be refracted, that they passed through all substances, that nothing seemed to stop them. Certain things are more permeable than others. These rays will pass through wood easier than through glass. Glass, which is transparent to light, is more or less opaque to these rays. They pass through the denser metals with greater difficulty. These rays cannot be bent. The only thing we can do is to make a shadow picture, and the shadow of the substance is developed upon the plate. It is entirely different from ordinary photography. Prof. Roentgen then tried to reflect the ray to see if anything would turn it from its course by reflection. He was

wholly unable to reflect it. He thought possibly he had succeeded in refracting and reflecting these rays to a slight extent, but he was not sure of it. A substance in the form of a very fine powder ordinarily does not pass light through. The fine particles of matter reflect the rays of light in every direction, and none go through powder with as great ease as they do through the metal of which the powder was made. The X rays pass through the powder as easily as through a solid. Then he tried to polarize the rays, but they are not subject to polarization. He has suggested that the rays may be longitudinal, instead of transverse.

Dr. Dayton C. Miller, on Roentgen Photography, reported as follows :—

I think probably it would be interesting to the Club to exhibit a few photographs and let you judge of the results of the Roentgen photography for yourselves. The first thing we tried, four weeks ago, at Case School of Applied Science, was to photograph a coin placed on the outside of the box which contained the sensitive plate. After an hour's exposure this picture was made. It shows an indistinct outline of the coin upon the plate.

In the work at the college we became more interested in the practical application than the theoretical part of the subject. Of course, we are interested in the theoretical part, but we want to know what it is and what it will do before we begin to theorize about it. We have photographed the bones of the fingers just as Roentgen has. Afterward we placed opaque bodies, such as keys and rings, under the fingers and obtained photographs with an outline of these articles through the hand. Next, we determined whether foreign substances in the hands could be detected, as well as deformation of the bones. We experimented for a time by placing bullets under the hand, and the bullets have been shown with perfect ease. One of the most difficult experiments was photographing through the foot with the bullet placed under the heel, and we succeeded in obtaining an image of the bullet in five minutes. After having photographed these bullets, we found some real subjects who had bullets in their hands. One is a gentleman in the *Leader* printing office, who shot himself while a boy, the ball entering the palm of his hand and going toward the wrist. He has always supposed that the ball was located in the arm between the wrist and elbow. The arm was photographed from the wrist to the elbow. The picture developed with perfect distinctness, but we did not find the bullet. Then we photographed the hand, and the first photograph indicated a very suspicious spot; the second photograph indicated a small ball at the bottom of the little finger. This gentleman was once a type-setter, and he had to give up the business because it caused him such pain, and it was because the ball irritated the nerve. Another picture is the Marshal of New Philadelphia, who has a bullet in the back of his hand. The doctor probed for it and was unable to locate it. Five photographs were taken, and every one located the bullet in exactly in the same spot, where the thumb joins on to the wrist bones, and the bullet will now be extracted. These are the only surgical cases we have undertaken so far. Among the better pictures which we have taken more recently is one of an aluminum medal, which shows the letters very distinctly.

The thicker parts of the human body have not as yet been tried. It takes too long a time. The photographic plate is placed in an ordinary box in which it is carried around for taking pictures. The plate is never uncovered in that box, so that there is no possibility of the plate becoming light struck. A pasteboard box offers no resistance to the rays. The hand, when photographed, is strapped to the plate holder, in order that the bones may be brought as close to the plate as possible. The earlier exposures varied from one to three hours. Our present expos-

ures vary from nothing to twenty minutes. A bullet has been located in eight minutes. We have secured an image of the ends of the fingers in thirty seconds with which it was possible to obtain an outline of the bones. The arm to be photographed having been strapped to the plate, a Crookes tube is placed above the kathode pointing towards the arm which is to be taken. The tube consists of a globe of glass made cylindrical or spherical, exhausted to a very high degree. The coil in use discharges sparks six inches long. It looks like a small streak of lightning; as the tube is more and more exhausted the spark changes into a broad band and grows larger till the inside of the globe is all aglow. Then still further exhaustion causes the glow to lessen, and the tube becomes fluorescent. It is supposed that the pressure is only about $\frac{1}{1000000}$ of an atmosphere inside of it at that time, and that the particles which strike the kathode become charged and are repelled from it, and that those particles in being driven away from the kathode have a chance to move to the other side of the glass before striking anything. That part of the glass becomes so hot one cannot hold his finger on it, and it can be made so hot that it will break the glass. The whole globe is more or less fluorescent. The light is a sort of a greenish-yellow color, always moving and shivering, very much like the Northern light. In order that one may see it, the room must be darkened, although darkness does not aid in the experiment. An English physicist named Crookes was the first to experiment with the phenomena of discharge in a high vacuum, and his tubes are called Crookes tubes, and they have been used in these experiments. The induction coil is the same which is familiar to you all. It is excited by eleven cells of storage battery, but it may be excited by a Grove battery. There is a peculiarity about the photographic plates in that "slow" plates seem as sensitive to these rays as the "fastest" plates. A lantern slide plate is nearly as sensitive to this work as the lightning plates used for snap shots!

MR. H. H. PORTER.—Can you make a shadow from an object some distance from the plate?

DR. MILLER.—Yes, but the shadow would be more indistinct. It would be a mere umbra. The rays start out perpendicular to the surface of the glass, and it has been supposed that they originate on the fluorescent glass. That may not be true. It hardly can be demonstrated.

MR. RICHARDSON.—Does the positive electrode or anode make much of a picture?

DR. MILLER.—It has been stated that the anode is the only important quantity, but others think it is the kathode. All our experiments point to the fact that it is the rays which strike out from the kathode which give direction, but I think the anode has something to do with it.

Professor Benjamin himself, on Mechanical Engineering, gave the following report: One of the most interesting developments in the use of steam is found in the use of high pressure steam. In Cornell University, experiments are made with steam 500 to 700 pounds to the square inch, and they have succeeded in obtaining greater efficiency than is possible with steam at lower pressure. They intend carrying those experiments still farther. The subject of determining the moisture of steam has been investigated, and it has been found that all calorimeters, as usually applied, are practically worthless and entirely misleading. The calorimeter is not at fault, but it is impossible to collect a fair sample of the steam.

The increase in the number of fly-wheel accidents has been marked the last two years. A gradual change is being made in this kind of construction, and the number of steel wheels is increasing.

With the subject of smoke prevention you are all familiar. There is no difficulty whatever in preventing smoke. There are eight or ten different stokers in the market, but it still requires a certain amount of brains to operate them, and the only way to prevent smoke, besides getting a mechanical stoker, is to pay more than a dollar a day for a fireman. There is one great fallacy prevalent, and that is that a boiler with a stoker cannot be crowded. It is not necessary to limit the capacity of the boiler when a stoker is applied. The other day we evaporated steam (equivalent to 100 horse-power from a 50 horse-power boiler) without any smoke, and we could do that night and day, except at such times as it is necessary to clean the grates at the bottom. You cannot see that there is any fire in the boiler from the appearance of the chimney. It is our intention this year to push these experiments not only in the school, but elsewhere.

In machinery, one of the principal developments is the increased use of the milling machine, which is gradually superseding the planer. The use of electricity in shops as a motive power is becoming more common. The Baldwin Locomotive Works have expended 75 per cent. of their gross power in running their shafting, and they have, to a considerable extent, replaced their shafts by wires. There is considerable progress in this direction, especially in shops where the works extend over considerable space of ground, and in separate buildings. We have two students this year engaged in going around among establishments in this city to determine the relative consumption of power by the actual work done. It shows that in many cases the introduction of electricity would be a saving, and in other cases it would not be advisable. It depends on location.

The general tendency in mechanical engineering and manufacturing seems to be towards studying more carefully the minor economies. As competition becomes more keen, and especially during these hard times, men have learned not to despise small things, and they devote more of their time and education to tying up the little loose ends.

All these reports were accepted and ordered spread upon the minutes.

The report of the Librarian was read as follows:

The Association of Engineering Societies has been decreased by the withdrawal from the same of the Western Society of Engineers. The cost of publishing the JOURNAL has been cut down so as to keep it within the $3.00 limit. This has been done by cutting out the Index Department and by condensing reports of proceedings as much as possible, cutting down discussions, and in every possible manner reducing the cost of publication.

The Association elected S. E. Tinkham, of Boston, Chairman, and John C. Trautwine, Jr., Secretary for the ensuing year.

The Library of the Club has been reorganized and will in future be a credit to the Club. A contract has been entered into with Case Library by which the library will care for our books and pamphlets the same as their own; they will expend, annually, in the purchase of engineering books, the same amount as we subscribe, and the result must be a very valuable collection. The purchases will be made by a joint committee consisting of the Library Committee of the Club and the Librarian of Case Library. The Club has already subscribed $210.00 for this year, and has agreed to continue the subscription annually for five years. This enables us to purchase $420.00 worth of books this year. Half of these belong to the Club, and are stamped with the Club's stamp, and the other half to Case Library, and the Club may remove its share in case of the severing of the present relations with the Library.

This condition has been arrived at principally through the efforts of Mr. John L. Culley, who first suggested the subscription, and who carried the matter to a successful conclusion.

The report was received and ordered spread on the minutes.

The annual address of the retiring president was read as follows and accepted and ordered spread upon the minutes.

ANNUAL ADDRESS
BY
PRESIDENT AUGUSTUS MORDECAI.

I do not think that we can be considered vainglorious if, for one evening in the year, at least, we should review for a moment the achievements of the Civil Engineer, and consider, somewhat boastfully perhaps, what he has accomplished in the world's progress, and to how great an extent the members of modern communities are indebted to him for the means of carrying on their various occupations, and for the comfort and well-being of their daily lives. Civil engineering is essentially a profession of peace and civilization. Amongst the most savage tribes of Africa or Patagonia you will find always the Military Chieftain, the High Priest, and generally the Medicine Man, but it is only in the more advanced tribes that anyone having the smallest resemblance to the Civil Engineer can be discerned. It is amongst those communities that have made the greatest progress and that are characterized by the highest intelligence, that the Civil Engineer finds his most favorable environment, No other profession has made such advances in recorded times. The ideas of a God one and indivisible and of vicarious atonement, the cardinal principles of modern theology, are clearly set forth in the Book of Genesis, one of the earliest historical records we have. The laws enunciated with such sublime effect on Mount Sinai contain nearly the whole principles of criminal jurisprudence, as those afterwards given by Moses of civil jurisprudence. The marshalling of the children of Israel into companies of fifty and companies of one hundred, and the subsequent campaigns of Joshua, show well-developed germs of discipline, tactics and strategy; and while it may be true that germs of the modern blast furnace, more or less microscopic, can be discovered in Tubal Cain's forge, yet nowhere can be found any discoverable protoplasm of the modern applications of the forces of steam and electricity. Does not the very application of the term "learned," to some of the other professions, go to show that to be thoroughly versed in them, it is necessary to study the language, manners, laws and customs of people now scattered and lost?

In the Jewish Talmud, that mine of apt parable, there is told a story that runs somewhat in this wise:

When Solomon had finished building the temple, he gave a feast to the principal officers who had helped him, and the one who had done the most toward the work, or who represented the most useful craft, was to occupy a seat of honor on his right hand. The company, after assembling, was to choose who was to be thus distinguished. When, however, the guests came to the banquet hall, what was their surprise to find an humble Blacksmith seated in the seat of honor. Solomon, provoked, asked the Blacksmith why he was there. "Did he not know that the chair was to be occupied by the one who had done the most in building the temple," and turning to his guests asked if they knew him. He who carved the Cherubim said: "This is no Sculptor; I know him not." He who inlaid the roof with gold said: "Neither is he of those who work in refined metals." He who worked on

the walls said : "He belongs not with those who are cutters of stone." And he who shaped the timbers said : "We who are skilled in framing and joining know him not." The King turned to the Blacksmith, who, nothing daunted, said : "But, O King, who made the fine chisels that the sculptor used, or the sharp knives and saws of the framers in wood, or the tools of the metal worker, was it not the Blacksmith? When they wish to deride me they call me a 'Blacksmith,' when they wish to praise me, they call me 'Son of the Forge,' but what would they do without my labor first?" Said Solomon, wise man that he was, "You have spoken truly, O 'Son of the Forge,' and you can keep the seat to which you are entitled and be our guest." "Thus," said the Rabbis, "Solomon acknowledged the dignity and importance of labor," and so may we not say to our military brother, waiting for "the cobwebs to be brushed from the cannon's mouth,' to find how good is his work and dreading all the attendant horrors, what could you have done if it were not for the tools we have placed in your hands; to the Physician, how could you have checked disease were it not for the pure water and ample drainage systems that we have given you ; to the Surgeon, what could you haye accomplished without the fine instruments that we have rendered possible, and so on through the list.

It is the misfortune of the Civil Engineer that he is an agent and works through agents. His achievements are produced, not by personal intercourse, but through his agents, and he is obliged to have financial means to carry out his plans, so that often his efforts are overshadowed by the financier on the one hand and the contractor on the other, and yet, it is his knowledge and experience that we must depend upon for our safety, comfort and happiness. Fortunately, all of us are not ill all the time, nor are we always in need of spiritual or legal advice, but every one of us, from the time of using the water spigot in the morning, immediately after rising, to the time of turning off the gas or electricity, immediately before retiring, depends upon the skill and experience of the Civil Engineer, shown, not by personal contact, but by ever-present results. Another misfortune he labors under is, that the result of one man's efforts is shared by thousands. Every one obtaining the benefit of his work does not have to come in personal contact with him, and his failures as well as his successes are immediately apparent. Of the hundreds of thousands of people, for instance, who cross the Brooklyn Bridge every day, all know the name of the Doctor they consulted last year, perhaps; of the Lawyer who tried a celebrated case last week ; many know the name of the gallant soldier who commands Governor's Island on their left, or that of the brave admiral who heads the navy yard on their right ; but I venture to say there are few who remember the name of the talented engineer who built the bridge, and few, very few, that of the skilful and accomplished gentleman by means of whose knowledge and experience they are enabled to cross every day so rapidly and safely, and I am afraid there are very few in this room, Civil Engineers as we are, who could name him.

It was only after the true principles of the correlation and the conservation of forces were discovered and understood, that the advances in the result obtained took such wonderful strides. As soon as man gave up the idea of being equal to his Creator, and learned that forces never die, but that they are perpetual, only taking different forms, and that they are related one to another; that heat meant motion and motion could be turned into power through steam and electricity; and that power could be directed in endless ways and accomplish nearly endless results, the wonderful advances of the last one hundred years took place. When he ceased to be an alchemist and became a chemist, what a list of achievements must be credited to him!

If Civil Engineering is "the art of directing the great sources of power in nature for the use and convenience of man," go where you will, turn which way you please, you see evidences of the handiwork of the Civil Engineer. It would take 30,000,000 camel loads to transport the tonnage of the city of Cleveland alone for one year; it would take a month for a camel, with 1,000 pounds on his back, his usual load, to go from Cleveland to New York; it would require a bucketful of water to be lifted three times a minute, day and night, from 2,000 wells, to supply the wants of this city alone, and so we might make endless striking comparisons.

The advance is so enormous that it is hard to realize. Certainly, no other profession can show such achievements, and the names of Pontius, Michael Angelo, Watt, Fulton, Stephenson and Edison should shine with equal lustre with those of Galen, Harvey, or Pasteur, St. Augustine, Luther or Wesley, Cicero, Blackstone or Marshall.

"But," says the critic, "you are degenerating. We see many evidences of the works of the architect, the road maker, the bridge builders, etc., of 1900 years ago. Where will most of your work be 1900 years hence, when the earthquakes and the fires and the storms have had a chance to wreck them? Will the New Zealander, so dramatically pictured by Macaulay, have any remains of London Bridge to sit on, or will any ruins of St. Paul be visible to him? The modern work of which you boast is slight, flimsy, ephemeral." Perhaps so, but how admirably adapted for what it has to do; as admirably adapted for its work in this stirring, changing (because progressive) age, as the Coliseum, the Pantheon, the bridges across the Tiber, Alexander's Aqueduct and the Appian Way were in those days. We are not called upon to build huge amphitheaters for witnessing fights of savage beasts; or temples to all the Gods; to carry water by gravity, alone, hundreds of miles; to erect stone bridges, which, by their mass alone would stand; or roads for light chariots; or camels or horses for the use of but one great community; but we are called upon to erect numerous churches to the one God; comfortable homes for all; office buildings for the accommodation of the greatest number at the least expense; pumping engines which have a capacity sufficient not only for the use but for the abuse of millions of people; bridges of iron and steel so admirably proportioned that not a pound of metal is lost; roads for heavy travel or for thundering locomotives, traveling with the greatest rapidity, hauling long trains of cars loaded with every conceivable product of the soil, the mines and the manufactories, from every nook and corner of the world; or palaces, carrying conveniently and luxuriously, delighted passengers; literally for the use of thousands of communities of greater population than the old city of Rome.

Conditions have changed and our work has changed to meet them, and we have brought just as much knowledge and learning and thought to the task, and our individual achievements have been just as good and glorious in their way as those of our professional brother at any time in the world's history, and it is the recognition of this fact, and of the extent to which they are indebted to the skill, perseverance, knowledge and experience of the Civil Engineer, that we should impress upon all, and this is one of the reasons why we should encourage Societies and Clubs, such as this.

We have had a fairly prosperous year, but there are many in the city whom we ought to have with us and draw into our membership, and we should see if we cannot attract them in some way, either by the excellence of our papers on subjects of current interest, or by the knowledge to be gained in the discussion of those sub-

jects in which many are interested, showing the experience of others and helping to solve some knotty problem; perhaps also by the toothsomeness of our lunches, fostering sociability and acquaintance among the members.

I know it is the wish of many members of the Club that we should have rooms of our own, and so far as our membership and income will allow, it certainly would be desirable. Though we have had a standing committee on the question, they have failed to report during the year, but I hope they have accomplished something. It might be possible to associate ourselves with some of the affiliated societies in the city looking towards leasing rooms; or perhaps some advantageous arrangement might be made with the owners of some of the new blocks that are now being erected, or of the old ones vacated. Our income has been too small to accomplish much, but it is a question whether we should not be more ambitious, try to make the social feature, especially for the younger members, a little more prominent, and whether we cannot now afford to spend more and have our own rooms better adapted for Club purposes, even if we continue our present arrangement with the Case Library for our meetings.

Much to the regret, certainly of the Clubs having a smaller membership, the Western Society of Engineers withdrew during the year from the Association of Engineering Societies. It is one of the Clubs having a large membership, and it is unfortunate, I think, that they should consider that their best interests lie outside of the Association. "In union there is strength," and it would seem that if we could have a journal for a number of societies, instead of a journal for each separate society, it would be much to be desired. Since the Western Society has withdrawn it has largely increased its advertising patronage, showing how much more effective work can be done for a local journal than for an associated journal, unless some one especially appointed gives his time to it. If a proportional amount of patronage could be obtained by each of the different clubs in the Association, the JOURNAL could be made a really valuable periodical, and I see no reason why this should not be done by energetic and persistent efforts.

Our membership has been decreased by the deaths of Messrs. Leggett and Reid. We did not see as much of General Leggett as we all wished, as he was a very busy man, with his time fully occupied. No words of mine can add to his record as a brave and gallant soldier, a learned and wise counselor, an accomplished and honest gentleman. Of Mr. Reid we saw more, and we learned to respect him for his knowledge and experience, and to esteem him for his many sterling qualities. He was a faithful and honest employee of the Lake Shore and Michigan Southern Railway Company for many years, and his work testifies to his ability and usefulness. With all he had a kindly and appreciative nature which endeared him to his many friends, and we shall miss him in the Club.

In closing and turning over to my successor the office with which you have so kindly honored me, I can only thank you for the honor and wish you a prosperous and profitable year.

The report of the tellers on election was read as follows:

President—Chas. S. Howe.
Vice-President—James Ritchie.
Secretary—Forrest A. Coburn.
Treasurer—Jas. C. Wallace.
Librarian—A. Lincoln Hyde.
1*st Director*—John L. Culley.
2*d Director*—Jos. C. Beardsley.

After some brief remarks by the newly elected officers, the meeting adjourned.

MEETING, April 14, 1896.—President Howe in the chair. Present, fifty-seven members and visitors. The minutes of the Annual Meeting of the Club were read and approved. Messrs. Palmer and Oliver were appointed tellers to canvass the ballots of B. L. Green and J. H. Sample for active members.

The Executive Board reported the resignations of three members and the transfer of two from active to corresponding membership, and the approved applications of nine persons for membership. Letter from E. S. W. Moore, at Wolverhampton, England, late of this city, was read. Also various communications from D. H. Hurley and others, from Washington, in regard to the Metric System.

The topic of the evening, "Smoke Prevention," was first taken up by Prof. C. F. Mabery, who was followed by Prof. C. H. Benjamin. They were followed by various other members, the conclusions arrived at being that in avoiding smoke is was necessary to have sufficient boiler, grate and stack capacity, and to have, on the part of the fireman, sufficient mental capacity. Mechanical stokers, and shakers were recommended as a saving both in labor and fuel.

The Program Committee reported as follows:

May 12.—*E. A. Sperry:* Steam Engine for Direct Connected Electric Generators.
June 9.—*Dr. C. O. Arey:* Water Supply and Sewerage as affected by the lower Vegetable Organisms.
July 14.—*James Ritchie:* Inspection of Structural Steel from the Standpoint of the Engineer.
Aug. 11.—*J. D. Varney:* Solar Work in Land Surveying and a New Mechanical Method for Doing it.
Sept. 8.—*J. N. Richardson:* A Paper on Architecture.
Oct. 27.—*C. L. Saunders:* Gas Producers and the Mechanical Handling of Fuel for same.
Nov. 10.—*J. R. Oldham:* Structural Strength of Ships; Efficiency for Repairing without Diminution of Strength.

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Jan. 12.—*Prof. S. H. Short:* Some Problems in Street Railroading.
Jan. 26.—*J. R. Oldham:* Steamship Propulsion and Analysis of Skin Resistance at Deep and Shallow Draught.
Feb. 9.—*Prof. C. H. Benjamin:* Use of Electric Motors on Machine Tools.
Feb. 23.—*Dr. Cady Staley:* A Paper on Sanitary Engineering.
Mar. 9.—*Annual Meeting:* Address by the President.
April 13.—*Dr. Cady Staley:* A Paper on Architecture.

The Standing Committees for the year were announced as follows:

Finance Committee:	*Library Committee:*
Jas. Ritchie,	A. Lincoln Hyde,
F. A. Coburn,	John L. Culley,
Jos. C. Beardsley.	Jas. C. Wallace.

Program Committee:

Wm. H. Searles,	S. T. Dodd,
J. R. Oldham,	C. E. Schulz,
Dayton C. Miller,	J. G. Oliver,

F. S. Barnum.

After the meeting, the Club repaired to the neighboring restaurant and enjoyed a visit and lunch.

F. A. COBURN, *Secretary.*

Engineers' Club of St. Louis.

434TH MEETING, April 1, 1896.—President Ockerson called the Club to order at 8.15 P.M., at 1600 Lucas Place. Thirty members and eight visitors present.

The minutes of the 433d meeting were read and approved. The Executive Committee reported the doings of its 212th meeting. An application for membership was announced from Mr. Albert Borden, of the engineering department of M. S. Cartter & Co.

Mr. Julius Pitzman then read a paper on "Municipal Engineering," his address having special reference to the laying out of grades and subdivisions, and of parks and public places. The address was illustrated by numerous maps and diagrams indicating the character of grades already established in St. Louis, and the serious mistakes which had been made in this work. Each plat also showed the grade which, in the speaker's opinion, should have been adopted. The enormous money losses due to these mistakes were also shown. Particular emphasis was laid upon the artistic features of the question, in order that the beauty and symmetry of our thoroughfares might be preserved. The essential features underlying the design of parks and boulevards were touched upon. The mistakes already made in our grades were, of course, beyond remedy, but the author deemed it necessary to impress upon all good citizens the importance of avoiding similar errors in the future. He called attention to places where similar mistakes would in all probability be made in the near future unless proper steps were taken to prevent.

Messrs. Robert Moore, Ockerson, R. E. McMath, Macklind, J. B. Johnson, and Spencer took part in the discussion, which was, on the whole, favorable to the speaker's ideas.

It was clearly brought out, however, that many difficulties surround the problem, and that the engineer could not always carry out his ideals, but must do the best he could within the limitations imposed upon him. Adjourned.

WILLIAM H. BRYAN, *Secretary*.

435TH MEETING, April 15, 1896.—President Ockerson called the Club to order at 8.35 P.M., there being twenty-nine members and five visitors present. The minutes of the 434th meeting were read and approved. The Executive Committee reported the doings of its 213th meeting, approving the application for membership of Albert Borden, of the engineering department of M. S. Cartter & Co. He was balloted for and elected. Applications for membership were announced from E. R. Fish and H. C. Meinholtz.

On motion it was ordered that the thanks of the Club be extended to Mr. Estill McHenry for presenting to the Club a number of very valuable photographs, maps, and drawings, formerly belonging to the late Capt. James B. Eads. Ordered, that the Secretary express in a formal letter to Mr. McHenry, the Club's appreciation of the donation. Ordered also, that proper acknowledgment be made to Col. E. D. Meier for donations of the back proceedings of the American Institute of Mining Engineers.

On motion it was ordered that a committee of three, with the President as chairman, be appointed to co-operate with the local members of the American Society of Mechanical Engineers, for the entertainment of their coming convention,—the members of this committee not to be members of the American Society of Mechanical Engineers. The President announced that he would appoint the committee later.

President Ockerson, having to leave at this time, called Mr. B. L. Crosby to the chair.

Mr. Carl Gayler then read a paper on "Highway Bridges." He reviewed briefly the movements in the direction of reform which had heretofore taken place, particularly the agitation of 1890, and gave his views as to why those movements had accomplished so little. He explained a typical case of highway bridge design, and described an accident to the Broadway bridge over the River Des Peres, in South St. Louis, where a contracted water-way had resulted in scouring out a deeper channel, and undermining one of the abutments. He thought it proper, in designing highway bridges, to use lower unit strains than is customary for railroad bridges, rather than higher, as is the general practice. In general, railway bridge practice could, in his opinion, be followed to advantage in highway work. He also discussed lateral top bracing, painting, and inspection.

Messrs. Eayrs, J. B. Johnson, Pitzman, Crosby, French, Russell and Baier participated in the discussion. Adjourned.

WILLIAM H. BRYAN, *Secretary.*

Technical Society of the Pacific Coast.

REGULAR MEETING, April 3, 1896.—Meeting called to order by Vice-President Curtis. Minutes of meeting of March 6, 1896, read and approved.

The following gentlemen were declared elected to membership by regular ballot: F. S. Edinger, Inspector of Bridges, Berkeley, Cal.; W. S. Keyes, Mining Engineer, San Francisco, Cal.; Russell L. Dunn, Mining Engineer, Auburn, Placer Co., Cal.

A letter from the Metrological Society, New York, was read, calling attention to the bill favorably acted on by the Committee on Coinage, Weights and Measures, House of Representatives, making use of Metric System obligatory after certain dates. Attention was called to the importance of vigorously endorsing the measure.

G. W. Percy moved that the Secretary be directed to address a communication to our Representatives in Congress asking for a support of the measure to make the use of the Metric System obligatory. Carried unanimously.

Mr. Reece, of the American Society of Civil Engineers, then addressed the Society on the subject of "Recent Improvements in Maintenance of Way."

Discussion of Mr. Reece's address was participated in by Mr. J. H. Wallace and Vice-President Curtis.

Mr. Randell Hunt read a paper entitled "Principles Governing the Design of Foundations for High Buildings."

The discussion of this paper was participated in by Prof. Marx, J. H. Wallace, G. W. Percy, Prof. Wing, Prof. Soulé, D. C. Henny, John B. Leonard and Vice-President Curtis. Adjourned.

C. E. GRUNSKY, *Acting Secretary.*

Association of Engineers of Virginia.

THE regular informal monthly meeting of the Association was held April 15, 1896, with President D. C. Humphreys in the chair. H. R. Bill 7251, to fix the standards of weights and measures by the adoption of the Metric System of weights

and measures was taken up and discussed. On motion, the Secretary was instructed to get at once a letter-ballot from the members of the Association, as to whether they favor the passage of the bill, or not, and to inform the Senator and Representatives of our State of the result.

Senate Bill 2301, to establish engineering experimental stations in connection with the colleges established in the several States, under the provision of an Act approved July 2, 1862, and acts supplementary thereto, was taken up and discussed, and, on motion, the Secretary was instructed to get the opinion of the members by letter-ballot, and to report results, as on H. R. Bill 7251.

H. R. Bill 3618, to organize and increase the efficiency of the personnel of the Navy; to increase the usefulness and numbers of the Corps of Naval Engineers; to induce the scientific institutions to provide a naval-engineering reserve for time of war; to establish a naval-engineering experimental station, and to encourage the study of the mechanic arts and sciences, and particularly that of naval engineering, in the technological colleges of the country, was taken up and discussed, and, on motion, the Secretary was instructed to proceed as with the other two bills.

The subject for the evening, "Engineering Ethics," was called and opened by Prof. L. S. Randolph, of Blacksburg, who showed clearly the necessity for some code, as well as the difficulties of making and enforcing it. The discussion was very generally entered into by those present, all seeming in favor of establishing some standard for the guidance as well as for the protection of the profession.

The directors have decided to have the Summer meeting at Pulaski, Va., June 26th and 27th. Detailed information of arrangements will be furnished later. The entertainment committee desire papers from the members. Send subjects to the Secretary.

ROANOKE, VA., April 16th, 1896. JNO. A. PILCHER, *Secretary*.

Montana Society of Civil Engineers, Helena, Mont.

AN adjourned meeting of the Montana Society of Civil Engineers was held Saturday evening, April 18th, in the Society's rooms in the Granite Block. There were present W. A. Haven, Finlay McRae, F. J. Smith, James S. Keerl, A. E. Cumming and James M. Page.

The application for membership of Abram L. Jaqueth, city engineer of Kalispell, was read and approved, and the Secretary was directed to send out ballots to be canvassed at the May meeting.

James S. Keerl and A. E. Cumming were appointed tellers to canvass the ballot for admission to membership. Upon the result being announced the chairman declared that John W. Young, of Salt Lake City, and John French, of Great Falls, had been elected.

Mr. Keerl, of the committee appointed to attempt to secure an amendment to House Bill No. 1470, to include the appointment of at least one civil engineer upon a national commission to supervise the design and construction of public buildings, reported that the matter was progressing satisfactorily, and that he believed the bill would be so amended that the commission would consist of the supervising architect, two civil engineers and two architects. That was encouraging, and Mr. Keerl was directed to continue to exert his influence to that end.

A letter from Gen. W. A. Haven, resigning his position as trustee of the So-

ciety, owing to the fact that he will in a short time remove from the State, was read. Numerous regrets were expressed that one who had done so much to advance the interests of the Society and the profession generally was about to leave. The resignation was accepted, and a committee consisting of Messrs. Keerl, Herron and Page, was appointed to draw up fitting resolutions embodying the regrets of the Society upon the departure of Mr. Haven from the State to engage in professional work elsewhere.

F. J. SMITH, *Secretary*.

Boston Society of Civil Engineers.

ANNUAL MEETING, MARCH 18, 1896.—The annual meeting of the Society was held at its rooms, 36 Bromfield Street, Boston, 7.55 P.M., President Albert F. Noyes in the chair. Ninety-nine members and visitors present.

The record of the last regular, and the special meeting of February 26th, were read and approved.

Messrs. James F. Bigelow, Arthur E. Horton, George E. Howe, Will B. Howe, Louis C. Lawton, Dana M. Pratt, Henry A. Varney, and Russell H. Whiting were elected members of the Society. Past President George L. Vose was elected an honorary member.

The amendment to By-law 10, proposed at the last meeting, so that the first two sentences shall read: "The entrance fee shall be ten dollars. The annual dues shall be *eight* dollars for members and associates residing within thirty miles of Boston, and *five* dollars for those residing at a greater distance, payable in advance at the annual meeting," was adopted, 35 in favor and none against.

The annual report of the Board of Government was read by the Secretary, and on motion it was accepted and placed on file.

The annual reports of the Secretary and the Treasurer were read by these officers, and on motion were accepted and placed on file.

Mr. Main presented the report of the Committee on Weights and Measures, and on motion it was accepted and ordered to be printed in the proceedings of the Society.

Mr. Wood read the report of the Committee on Excursions, and on motion it was accepted and placed on file.

Mr. Doane made a verbal report for the Committee on Quarters, which was accepted.

Mr. Flinn presented the report of the Committee on the Library, and on motion it was accepted and placed on file. On motion of Mr. Blodgett, the recommendations made in the report of the Committee on the Library were referred to the Board of Government, with full powers.

On motion of Mr. Stearns it was voted to refer to the Board of Government, with full powers, the question of continuing the several special committees and the selection of the members thereof.

The President read a communication from the President of the Western Society of Engineers in relation to a bill before Congress looking to the appointment of a Commission on Public Architecture. He also reported, for the Board of Government, by whom the matter had been considered, that the Board did not think it advisable for the Society as a body to take definite action in the matter. The communication was received and placed on file.

Mr. Henry A. Phillips read a paper on certain aspects of the relations between the work of the architect and the engineer. The paper was mainly devoted to a

plea for the preservation of the Bulfinch front of the Massachusetts State House. It was discussed by Messrs. L. F. Rice and E. P. Adams.

Messrs. W. B. Fuller and C. E. Putnam, the tellers appointed to canvass the letter-ballots for officers, submitted the result of their count. There being no election for Vice-President and Librarian, the meeting proceeded to choose these officers from the two candidates for each office having the highest number of letter-ballots. As the result of the letter-ballot and the choice of the meeting, the President announced the following officers elected:—

President, George F. Swain.
Vice-President (for two years), Henry D. Woods.
Secretary, S. Everett Tinkham.
Treasurer, Edward W. Howe.
Librarian, Alfred D. Flinn.
Director (for two years), Frank W. Hodgdon.

President Alfred F. Noyes then delivered his annual addresss.

ADDRESS OF PRESIDENT NOYES.

It has been the custom for the President of your Society at the annual meeting to give a general review of the progress made during the year, in the execution of engineering works, and to give a summary of the results obtained. It is not my intention to-night to refer, more than in a general way, to the engineering achievements and works now being carried on or almost completed, and to refer to the progress made in engineering in our own State, a territory which may be assumed to be the special jurisdiction of this Society; but it is my intention to speak to you more with regard to the future of the Society, and to offer suggestions as to means for increasing its usefulness, both to ourselves and to the profession at large.

The Society will, in July of this year, have been organized forty-eight years. These years have seen a wonderful growth in the usefulness of the profession, and the public have come to depend upon and place greater confidence in the advice of the engineer, not only in the preliminary consideration of all questions relating to public improvement, but in carrying them to successful completion.

Probably in no State in the Union has so much been done by the General Government as has been done by the Government of the State of Massachusetts, in the way of authorizing great engineering works, and in making possible careful investigations upon engineering questions, from the results of which information is obtained of great permanent value to the whole country. The appropriations enabling the State Board of Health to continue the investigations and experiments carried on at the Lawrence Experiment Station, to maintain a more complete supervision over, and to continue the examination of the water supplies, as well as the examinations to determine the results obtained by the operation of the various sewage disposal works in the State, have been continued, and has been even more liberal than for previous years. During the year the construction of both the North and South Metropolitan Sewerage Systems, which were begun in the year 1890, have been practically completed and put in operation. The investigation, made under the direction of the State Board of Health, with regard to obtaining an increased water supply for the Metropolitan District, has been completed; and by authority given by special act of the Legislature, the work has not only been authorized, but has been begun. It may be of interest to note that the details of the plan of the proposed system have been so carefully considered that the appropriation providing for the construction of the work was made, and measures taken

contemplating the construction of the system without one word of criticism upon the plans.

The Metropolitan Park System, which contemplated the taking of large areas of unimproved land located in the Metropolitan district, and land having great natural attractions, has been extended so that there is now assured to the public forever the preservation of these great breathing and recreation grounds for the constantly increasing population of the Metropolitan District.

The work of constructing the subway, under the direction of the Boston Transit Commission, which will provide in a measure a way by which more rapid transit can be obtained through the congested portions of the City of Boston, has been well begun.

There has been a continued demand for the construction of State roads, as proposed by the Massachusetts Highway Commission in their report of 1893, and appropriations aggregating over $700,000 have been made and expended under the direction of that Commission, and has enabled them to construct 89.91 miles of road with stone or McAdam surface, and has demonstrated to the various municipalities the benefits to be derived by the construction of these roads, as well as the economy affected, and comfort and convenience resulting from their use. This object-lesson has led to a demand for a still greater extension of the State Highway System, with requests from the authorities in all parts of the State for an appropriation this year of from one to two million dollars.

Investigations have been made and plans proposed, through a special commismission, for the improvement of Boston harbor. Sewer systems have been designed, construction begun or extended in nearly if not quite all of the municipalities in the Metropolitan District.

Nearly all of the cities and some of the towns in the State have organized and maintain a department of municipal engineering, and some of the cities and towns have recognized the value of the services of the Consulting Engineer to advise upon the special work of the department, and have regularly retained the services of such an officer. Nearly all of these municipal offices have been filled and works executed by or under the direction of members of this Society ; and the members of this Society have still further been recognized as administrative officers by the appointment of at least one of its members on most of the State Commissions having anything to do with or requiring the services of the Engineer ; and so assured is the confidence of the public in the ability of the engineer that no work of any importance is undertaken without first being investigated and reported upon by him. It is but rare that any work is placed in his hands without first looking up carefully his professional experience and reputation ; and it is an encouraging sign that the question of price to be paid for his services does not, except in a few cases, actuate the client in his selection of an engineer, but that professional reputation and experience is of first importance.

Each year has seen an increase in the membership of the Society, and during the past year the increase has been larger, and the interest in the meetings, as shown by the attendance, has also been greater than during any previous year. With this increasing membership, and increasing demands upon the service of the engineer for all classes of work, there has been a natural tendency for specializing their work ; and in order that the greatest amount of benefit may be obtained by each individual member, it becomes necessary for us not only to consider but to realize that the members must be provided with the literary food which their tastes demand. The demands upon the profession have become so great that with each

succeeding year there is a greater tendency to specialize in its work, so that to-day the engineer who takes an advanced position in the profession, while he may have a general knowledge of and desire to keep informed with regard to all phases of engineering specialties, there is a tendency to devote his whole energies to one or more of the special lines where his interests will centre.

The Society has already become so large that there are sufficient numbers of representatives of almost every branch of engineering to form a nucleus for the organization of a separate society representing the interests of each branch. Already have the interests in water-works and highway construction and maintenance become so great that branch organizations have been formed which have included in their membership a large number of members of this Society. Included in the membership of these societies are the practical operating men in their special lines, and men who would not, in some respects, from their experience be eligible for membership to this Society. Attendance at the meetings of these societies bring our representatives in contact with the active men in the work they are engaged upon, and they get a benefit which would not be obtained at the meetings of this Society; hence I do not look upon these organizations as being in any way a menace to the interests of this Society.

There are, however, other branches of engineering, namely, the Mechanical, the Marine, the Railroad, the Municipal, the Electrical and the Sanitary Engineer, whose membership in the Society have become so large as to lead some to seriously consider the organization of societies or clubs dealing with questions of special interest to their branch of the profession. There does not appear to be the large field from which to draw any considerable number of persons to such societies or clubs if formed, who would not be eligible for membership to this Society; hence the organization of such societies can be considered, if withdrawing attendance and interests in this Society, as a means of decreasing its usefulness.

The question now before us, as the membership increases, and its numbers become so great as to make the body in some respects unwieldy, is how to get the greatest possible good to all working in the special lines which the profession is bound to divide itself into. As it is necessary that each specialist should be in touch with the other's works, it is, I believe, by the work of this Society, that these results can be accomplished.

The literary portion of the exercises at our monthly meetings has generally been provided by members of the Society, and has consisted of a description of work being carried on, executed, or investigations made. The papers have generally been obtained either by the voluntary offer of the members, or at the solicitation of the Secretary or President of the Society. The topics considered have usually been suggested by these officers; and from their comparatively limited knowledge of what may be going on in the various branches of the profession, it is not at all surprising that a larger amount of desirable information is not obtained. The informal library meetings, so successfully begun and continued during the past two years, have been a source of great interest and profit to the members, and this interest is increasing, so that on several occasions the meetings have been held in the small hall in the rear of this hall.

I have frequently heard criticism or complaint offered from members representing special branches of engineering in the Society, as an excuse for not taking more interest and attending the meetings; that the papers read were not of special interest to them. My answer to these critisms has invariably been that it was their place to take hold and offer to the Society the results of their best work and inves-

tigation upon these lines of special interest to them. This will have the effect of bringing out discussions, and the mere putting in shape of a paper sufficiently carefully considered to justify submitting to the Society will be of great personal benefit to the members undertaking it. It is only by organization, each doing his share, and that share is all that each is capable of doing, that the best possible results can be obtained.

In our new quarters there will be ample room for gatherings of any considerable body of the Society. I would suggest the following form for sub-organization: That committees of the Society be formed, these committees containing within their numbers the members representing the various branches in the profession, and might be called committee on Architectural, Mechanical, Sanitary, Hydraulic, Railroad, Municipal, Marine and Electrical Engineering. These divisions or committees may be made by the Board of Government, or the members may signify to the Board of Government their desire to become attached to one or more committees representing the special division or divisions of engineering work they are interested in. These committees would make up their own organization by the choice of a chairman and secretary, and it should be their duty to provide literary entertainment for both the regular and library meetings which would be assigned to them, and they to consult with each other as to in what way papers of the greatest professional value can be prepared and presented at these meetings. A spirit of rivalry among the various committees could be encouraged by the offer of a prize or special mention for papers of merit prepared by the members of each. In order that there may be a unity of action between each of the committees, a central organization, consisting of the President and Secretary of this Society and the Chairman and Secretary of each of the committees, could be effected with the President and Secretary acting respectively as chairman and secretary of the joint committee. The interest in the work of the various committees can be still further increased by special literary or social meetings held at such time as they may elect other than the time of the regular meetings of the Society, and at which they could discuss topics of special interest to their branch.

By carrying out and developing the plan substantially as outlined, each member would be able to keep in touch with all branches of engineering work, which his special calling would not ordinarily permit, except from availing himself of advantages to be obtained by these meetings. Each would feel that he had a work to do, which can hardly be the case under the existing conditions of organization. I believe the carrying out of such a plan would bring to the Society the membership of many men interested in special lines of professional work, and result in the production of papers of greater professional value.

I understand that, in past years, a plan, somewhat similar to that outlined above, has been made part of the organization of the Engineers' Club of Philadelphia, by which special committees have been appointed, whose duty it was to provide literary entertainment for each meeting night during the year, the work of the year being laid out as soon as practicable after the annual meeting. I further understand, it was an unwritten obligation on the part of the members of that Society that these papers be prepared, and the execution of the plan has resulted in the preparation of papers of unusual professional value.

While dwelling upon the question of methods for increasing our usefulness, I cannot forbear to speak a word to the older members of the Society, and when thus speaking it must be borne in mind that each one who is older than the youngest may be included in this class.

Several of the guests at the annual dinner of the Society remarked as to the large number of young men there were present, and it could not but lead me to reflect that a considerable majority of the members of the Society were comparatively young men working in their own field, but striving to reach a higher position in that field, and to increase their usefulness. I have been frequently asked by the younger men, as I presume most of the older men of the profession have been asked, as to what course to pursue and the best way to prepare themselves to make more advanced standing in their work. At these times I can but recall the period when I have asked myself this question; and, in fact, the question is constantly recurring to me as I look about and see older persons in the profession than myself, and those who by application and persistent work have reached more advanced positions, I feel an inclination to ask the same question of them; and I am led to ask you to-night, fellow-members, are we doing all we can in our personal work to assist the younger members, both of the Society and the profession, and are we doing our full work, and work which will enable them to more quickly take the advanced standing in the profession which is sure to result in a benefit to us all?

These thoughts and suggestions I have only been able to present to you in a rough and undeveloped state, feeling that they are worthy of your future consideration, that by general discussion, which I would gladly invite, that which may be good in them may be culled out and result in the general good to all.

In closing I wish to thank the members of the Board of Government and the members of the Society for their cordial co-operation and assistance to me as their presiding officer. This co-operation and assistance has made the work of the year both easy and pleasant; and I can assure you I deeply appreciate the honor which has been conferred upon me by being selected to serve in the capacity of President during the past year, and I can safely predict that with each year there will be an ever increasing amount of good accomplished by the united work of the members of this Society.

At the close of the President's address the Society adjourned.

S. E. Tinkham, *Secretary.*

ABSTRACT OF ANNUAL REPORT OF BOARD OF GOVERNMENT FOR THE YEAR 1895-96.

Ten regular meetings and one special meeting have been held during the year and the fourteenth annual dinner of the Society was given on March 3, 1896. The average attendance at the regular and special meetings was 87, the smallest being 60 and the largest 142. The number present at the annual dinner was 170.

At the last annual meeting the total membership of the Society was 354, of which 348 were members, 4 honorary members and 2 associates.

During the past year we have lost 15 members: 5 by death, 4 by resignation, 1 by transfer to the Engineers' Club of St. Louis, and 5 by forfeiture for non-payment of dues.

There have been added to the Society during the year 50 members: 49 by election, and 1 who had resigned membership was reinstated. The net increase in membership has been therefore 35.

The present membership of the Society consists of 4 honorary members, 4 associates, and 381 members; a total of 389.

The records of deaths for the year is as follows:

John H. Webster, died April 2, 1895; Adelbert L. Sprague, died April 12, 1895; Marshall M. Tidd, died August 25, 1895; Willis H. Hall, died August 26, 1895; Horace L. Eaton, died November 23, 1895.

Negotiations have been had with the Committee of the Tremont Temple Baptist Church Corporation with a view of obtaining quarters in the new Tremont Temple Building, where not only the library, which is now owned by the Society, can be arranged so that it will be readily accessible for the use of the members, but where space can be had for increasing the library and making it an element of use and profit. This has resulted in a lease being taken of quarters on the seventh floor of the building for a period of three years, with the privilege of renewing said lease for three years more. The new quarters consist of one large room about 18 by 43 feet, of sufficient size to provide room for the proper arrangement of the present library, and for such additional books as will probably be obtainable for a period of several years. Arrangements have also been made for the joint use of the room with the New England Water Works Association, an association which has, to a considerable extent, kindred interests and work to that of our Society, and to which society a very large number of the members of this Society belong.

Adjoining the new room of the Society, on the floor below, is a large hall of ample size to accommodate the probable attendance to most of the meetings of the Society for several years to come. A popular subscription has been made for furnishing the rooms of the Society, and the amount of the subscription is about $712.00. It is hoped that this amount will be increased to about $1,000, which it is hoped will furnish a small sum to provide for the proper arrangement of the library and the cataloguing of the books.

ABSTRACT OF THE TREASURER'S AND THE SECRETARY'S REPORTS FOR THE FINANCIAL YEAR 1895-96.

CURRENT FUND.

Receipts.

Balance on hand March 20, 1895	$156 94
Received from dues of members	2,363 00
Received from rent of office to March 15, 1896	150 00
Received from sale of Journal	6 50
	$2,676 44

Expenditures.

Association of Engineering Societies	$1,356 31
Rent	500 00
Printing, postage and incidentals	345 47
Secretary's salary	200 00
Incidental expenses of annual dinner of 1895	72 90
Periodicals and binding	24 25
Expenses at meetings, stenographer and lantern	80 75
Cash on hand	96 76
	$2,676 44

PERMANENT FUND.

Receipts.

Balance on hand, March 20, 1895	$1,190 39
Forty-eight entrance fees	480 00
Payment of real estate mortgage	1,000 00
Shares of Merchants' Co-operative Bank, retired . .	428 72
Interest and dividends	127 29
	$3,226 40

Expenditures.

New shares in Merchants' Co-operative Bank	$351 84
Dues on shares in Co-operative Banks	775 00
Cash on hand, uninvested	2,099 56
	$3,226 40

SCHEDULE OF FUNDS OF THE SOCIETY, MARCH 18, 1896.

1 Republican Valley Railroad bond (par value) . .	$600 00
9 shares, C., B. & Q. R. R. stock (par value)	900 00
Shares in Co-operative Banks	3,040 65
Cash on hand, permanent fund	2,099 56
" " current fund	96 76
" " fund for furnishing new rooms	300 00
	7,036 97
Schedule presented at last annual meeting	6,022 50
	$1,014 47

REPORT OF THE COMMITTEE ON WEIGHTS AND MEASURES.

BOSTON, MARCH 18, 1896.

To the Boston Society of Civil Engineers:

GENTLEMEN :—The only definite and tangible thing which has taken place during the past year through the Committee on Weights and Measures is the passage, after much trial and tribulation, of the resolution :—

Resolved, That the Boston Society of Civil Engineers earnestly deprecate the use of any of the wire and sheet metal, or other trade guages now in vogue, and strongly urge the use of a *decimal system* for all such measurements.

A resolution similar to this has been adopted by several of the engineering societies in this country.

During the past year the Metric System of weights and measures has been made obligatory and exclusive by the Turkish Government.

The Bulgarian Government has issued a notification to the masters of ships bound to Bulgarian ports that, unless their cargoes are weighed in kilograms, they must be reweighed at the expense of the shipper.

According to the New York *Evening Post*, the United States, England and Russia are the only civilized countries not using the Metric System.

There is a bill before Congress, introduced December 26, 1895, which has been read twice and referred to the Committee on Coinage, Weights, and Measures, on which hearings have commenced before the Committee.

The Bill is as follows :—

A BILL

to fix the standard of weights and measures by the adoption of the metric system of weights and measures.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That from and after the first day of July, eighteen hundred and ninety-seven, all the Departments of the Government of the United States, in transaction of all business requiring the use of weight and measurement, shall employ and use only the weights and measures of the metric system, as legalized by Act of Congress approved July twenty-eighth, eighteen hundred and sixty-six.

Sec. 2. That from and after the first day of July, eighteen hundred and ninety-nine, the metric system of weights and measures shall be the only legal system of weights and measures recognized in the United States.

Sec. 3. That the tables in the schedules annexed to the bill authorizing the use of the metric system of weights and measures, passed July twenty-eighth eighteen hundred and sixty-six, shall be the tables of equivalents which may be lawfully used for computing, determining, and expressing in customary weights and measures the weights and measures of the metric system.

February 13, 1895, a Select Committee was appointed by the House of Commons to inquire whether any and what changes in the present system of weights and measures should be adopted.

July 1, 1895, the Committee made their report to the House of Commons, the summary of which is as follows :—

Your Committee recommend :

(*a*) That the metrical system of weights and measures be at once legalized for all purposes.

(*b*) That after a lapse of two years the metrical system be rendered compulsory by Act of Parliament.

(*c*) That the metrical system of weights and measures be taught in all public elementary schools as a necessary and integral part of arithmetic, and that decimals be introduced at an earlier period of the school curriculm than is the case at present.

These and other signs show that slowly, but surely, the metric system is advancing and that its use is gradually increasing.

In the issue of January 17, 1896, of that conservative paper, *London Engineering*, appeared an editorial on "The Metric System and Standard Screw Threads." We will quote a portion of this article :

"We regard it as an absolutely foregone conclusion that the metric system will be adopted here, and the only points open to discussion are how the transition can be made most easily," etc., . . . "but those that can read the signs of the time, now see its advancing shadow. Pushing firms, like Messrs. Williams & Robinson, have adopted it voluntarily, conscious of the immense advantage it gives them in the export trade, and others are casting about for the means to follow their example."

Engineering Record of March 7, 1896, states that the Engineering Association of the South has instructed its Secretary to write to the Tennessee members of Congress, urging them to vote in favor of the Metric reform.

The change which is proposed in the bill before Congress must be of great interest to the Boston Society. Judging from the action of the Society on the

resolution relating to Wire Gauges, your Committee feel that the Society would probably not care to take any action as a body, but if any members show a desire to obtain individual expressions of opinion of the members, the Committee will proceed to obtain these expressions as far as possible, for and against the proposed measure, in the form of signatures to petitions for and against the passage of the bill.

CHAS. T. MAIN,
ALLEN HAZEN,
DWIGHT PORTER, } *Committee.*

REGULAR MEETING, APRIL 15, 1896.—A regular meeting of the Society was held at its rooms, 36 Bromfield Street, Boston, at 7.50 P.M. Sixty-eight members and visitors present.

President George F. Swain, on assuming the chair, thanked the members for the honor they had conferred upon him in electing him to preside over the Society for the coming year.

The record of the last meeting was read and approved.

Messrs. Joshua Atwood, 3d, Maturin H. Ballou, Sidney K. Clapp, William C. Cuntz, John N. Ferguson, Fred G. Floyd, Henry K. Rowell, William J. C. Semple, and Fenwick F. Skinner were elected members of the Society.

The President announced the deaths of the following members of the Society:—William A. Allen, who died March 21, 1896, and Waterman Stone, who died March 30, 1896.

On motion, the President was requested to appoint committees to prepare memoirs. The Committees appointed consist of Messrs. E. W. Howe and H. Bissell to prepare the memoir of Mr. Allen, and Messrs. J. W. Ellis and E. B. Weston that of Mr. Stone.

On motion of Mr. Fuller the thanks of the Society were voted to the Quincy Market Cold Storage Co., and to Mr. Geo. H. Stoddard, its manager, for courtesies shown to members taking part in the excursion to its warehouses this afternoon.

The Secretary reported for the Board of Government that it had appointed the following special committees:—

On Weights and Measures, Charles T. Main, Allen Hazen and Dwight Porter.

On Excursions, E. S. Dorr, F. O. Whitney, W. E. McKay, E. S. Davis and Morris Knowles.

On the Library, A. D. Flinn, S. E. Tinkham, H. F. Bryant, M. S. Pope and W. B. Fuller.

On Quarters, Thomas Doane, Desmond FitzGerald, E. W. Howe, C. F. Allen and E. W. Bowditch.

Members of the Board of Managers, S. E. Tinkham, J. R. Freeman, Henry Manley and Frederick Brooks.

A letter was read from Prof. George L. Vose, accepting his election as an honorary member and expressing his thanks for the same.

The Librarian brought to the attention of the Society the desirability of reserving for the use of the library, a portion of the fund subscribed for furnishing the new rooms. After some discussion it was voted, that the custodian of the fund for furnishing the rooms be requested to reserve $100 of that fund for the procuring of a card catalogue of the library.

Mr. Joseph R. Worcester was then introduced, and read a very carefully prepared paper on Riveted Joints.

The paper was discussed by Mr. James E. Howard, Engineer of Tests at the Watertown Arsenal, and by Messrs. Lanza, Cheney, Hollis, Snow and Guppy of the Society. The Secretary also read discussions prepared by Messrs. E. S. Shaw and J. C. Moses.

Adjourned.

S. E. TINKHAM, *Secretary*.

Bradley & Poates, Engr's, N.Y.

ASSOCIATION OF ENGINEERING SOCIETIES.

VOL. XVI. | MAY, 1896. | No. 5.

PROCEEDINGS.

Engineers' Club of Minneapolis.

MINNEAPOLIS, MINN., APRIL 20, 1896.—The regular meeting of the Engineers' Club of Minneapolis was held at the office of the City Engineer, City Hall, at 8 o'clock P.M. The President, F. W. Cappelen, in the chair.

Communications in reply to letters relative to House Bill No. 1470 were read from Geo. F. White, M.C., "that he was in favor of adding Engineers to the Commission of Public Architecture;" from Lorin Fletcher, M.C., "that he would do everything he could to the same end;" from Knute Nelson, that "he would call the attention of the Committee on Public Buildings and Grounds, in the Senate, to the matter."

A communication from the Chicago *Journal of Commerce and Metal Industries*, stating they had placed our Club on the complimentary list. On motion the thanks of the Club were extended to them.

The menu of the 16th annual banquet of the Civil Engineers' Club of Cleveland, O., sent our President, was read and appreciated.

F. H. Constant was unanimously elected a member of the Club.

The committee appointed to investigate the matter of quarters for the Club in the New Court House and the Public Library, reported that there were no vacant rooms in either building.

On motion a new Committee on Quarters, consisting of F. W. Cappelen and G. C. Andrews, was appointed.

The names of Chas. E. Pillsbury and C. H. Kendall were proposed for membership by A. B. Coe and W. R. Hoag.

Mr. Loe sent word he had been unable to complete for this meeting his paper on Flour Mill Construction.

Mr. A. B. Coe read a paper on Measurement of Difficult Base-line, which was informally discussed.

Mr. F. W. Cappelen promised a paper on Electric Lighting.

On motion adjourned.

ELBERT NEXSEN, *Secretary*.

Technical Society of the Pacific Coast.

Regular Meeting, May 1, 1896.—Called to order at 8.30 P.M., by Vice-President Curtis.

The minutes of the last regular meeting were read and approved.

S. D. Schindler, Civil Engineer, of San Francisco, applied for membership; proposed by A. I. Frye, D. C. Henny and Randell Hunt.

The Secretary proposed the following, which was unanimously adopted:

Whereas, It has been made known to the Technical Society that the American Society of Civil Engineers would hold its annual meeting in the city of San Francisco, on or about the 28th of June, 1896, therefore, be it

Resolved, That this Society tender to the American Society the use of its rooms during its stay in our city; that we invite all visiting members to make their business headquarters with us, and to partake of the hospitalities of the Technical Society of the Pacific Coast, which are hereby cheerfully and heartily extended to all those who may visit California on this occasion.

A copy of this resolution was submitted to Vice-President Curtis, to be forwarded to the committees of the American Society of Civil Engineers.

The following communication was read:—

"It is the sad duty of this Society to chronicle the death of a man who, until within a short time of his demise, had been a prominent and active member of the Technical Society. It is suggestive and proper that reference be made to the life and history of Chas. A. Stetefeldt, who was well known to almost every member of the Society, and whose genial ways and kindly nature had endeared him to the hearts of all those with whom he came in contact. He died in Oakland, California, on the morning of March 17th, at the age of 57 years, after an illness of short duration. His death was entirely unexpected, and was to all of his acquaintances a source of heartfelt grief."

The following notes have been taken from a memoir written by an old colleague of the deceased, Mr. R. W. Raymond, who gave it publication in the *Engineering and Mining Journal*, of March 28, 1896:—

"Chas. A. Stetefeldt was born September 28, 1838, at Holzhausen, a village in Thuringia, Germany. He was educated at home by his father, a Lutheran minister, until, at the age of 14, he was sent to the Gymnasium at Gotha. While there he was one of the founders of the "Naturwissenschaftliche Verein der Gymnasiasten zu Gotha," a society which still exists and flourishes.

"In 1858 he entered the university at Goettingen, where he remained for two years, studying principally under Woehler, Wilhelm Weber, Sartorius von Walters hausen and Stern. He then went to the School of Mines at Clausthal, and passed there, in 1862, the 'Ingenieur-Examen,' receiving the first degrees in all branches. The following year he spent in the principal metallurgical works in Germany, especially at Freiburg, and emigrated in 1863 to the United States.

"A few days after his arrival in New York he was engaged as assistant by Charles Jay, Professor of Chemistry at Columbia College. It was in the following year that he became an assistant in the office of R. W. Raymond.

"He possessed a knowledge of mathematics and chemistry much beyond the usual equipment of a mining engineer or metallurgist, and, at the same time, an exceptionally wide scientific and literary as well as technical culture.

"In 1865 he established, with John H. Boalt (then a mining engineer, pure and simple) a branch office at Austin, Nev., in the then 'booming' Reese River district.

Soon after coming to America, he had taken out a patent for a special arrangement of the Gerstenhofer shelf-furnace for desulphurizing pyritic ores, but, after a single unsatisfactory trial in Colorado, the invention was practically abandoned.

"But out of his adverse experience the skill and genius of Stetefeldt extracted a conception of real and permanent value. Having satisfied himself that, especially in an atmosphere containing chlorine, as well as oxygen, the reactions of oxidation and chlorination were so rapid as to be (for particles sufficiently small, and sufficiently exposed to this atmosphere) practically instantaneous, he boldly discarded the shelves of the Gerstenhofer furnace, substituting the free fall of the charge in an open shaft. This invention, known throughout the world as the Stetefeldt furnace, was undoubtedly both a novelty and an improvement, though the precise limits of its advantageous use are still a matter of controversy. Whatever may be the ultimate result of the discussion, the name of Stetefeldt, in connection with this furnace, will remain indelibly imprinted upon the history of metallurgy.

"After the successful introduction of this furnace Mr. Stetefeldt went to Europe, in 1870, and did not return until 1872, when he made his headquarters at San Francisco. In 1882 he returned to New York, but took up his residence again in California in 1889.

"The latter years of Mr. Stetefeldt's life were largely devoted to perfecting the construction and operation of his furnace, and in operations in metallurgical practice, to which it was auxiliary. The most important of these was the Russell process of lixiviation, concerning which he published several papers and a text-book, the second edition of which appeared last year.

"One of his latest enterprises in connection with the improvement of silver mills was the introduction of producer gas for firing dry kilns and roasting furnace at the Marsac Mill, Park City, Utah, a new departure which promises to be of great importance, and will, no doubt, be generally adopted where wood can be profitably replaced by coal."

The following resolution was offered by C. E. Grunsky :—

Whereas, This Society believes John Hayes Hammond, who is one of its members, and who has been one of its executive officers, incapable of committing any offense against any Government, deserving death penalty, and will ever believe that his actions have been prompted by honorable motives, therefore, be it

Resolved, That a committee of three be appointed to take such action, from time to time, as may seem appropriate to mitigate the severity of the sentence imposed by the authorities of the Transvaal for his connection with the reform movement in that country.

The following committee was appointed, after passing the resolution unanimously: Messrs. C. E. Grunsky, Prof. Frank Soulé and Otto von Geldern.

The following letter was read :—

April 30th.

The Secretary of the Technical Society,
San Francisco, Cal.

SIR:—Allow me, through you, to call the attention of the Technical Society to Lord Kelvin's Jubilee, which is intended to be celebrated in Glasgow on the 15th and 16th of June next. This Society should appoint a committee to confer with the Astronomical Society and the Academy of Sciences, so as to have a reunion of scientists on that occasion and do honor to one of the greatest scientific authorities of this or any other age. It would be superfluous for me to refer to the life work of such a man whose name is so well known the world over.

This completes his fiftieth year as Professor of Natural Philosophy in Glasgow University, and as about all the recompense which a great philosopher receives is honor, I think we should show our gratitude for his great services to science by at least joining the rest of the world in our congratulations to him.

With respects, yours faithfully,

[Signed] ROBERT STEVENSON.

The letter was ordered to be received, and the Secretary instructed to consult with other societies and to co-operate with them in any event to honor the fiftieth anniversary of Lord Kelvin's professional career.

A discussion was opened on the present capacity and design of steel rail used in modern railway construction, in which Vice-President Curtis favored the meeting by stating his personal experiences and results in this line of railway engineering. This interesting discussion formed the topic of the evening, after which the meeting adjourned. OTTO VON GELDERN, *Secretary.*

Civil Engineers' Society of St. Paul.

ST. PAUL, MINN., MAY 4, 1896.—A regular meeting of the Civil Engineers' Society of St. Paul was held at 8.30 P.M.

Present, thirteen members and six visitors.

Mr. W. L. Darling in the chair.

The reading of minutes was dispensed with.

Papers in the matter of a Bill to establish Experimental Engineering Stations were referred to the government of the Society.

Mr. William de la Barre, of Minneapolis, read a paper on Recent Improvements of the Water Power at St. Anthony Falls, and was accorded a vote of thanks.

C. L. ANNAN, *Secretary.*

Engineers' Club of St. Louis.

436th MEETING, May 6, 1896.—The club was called to order at 8.40 P.M., 1600 Lucas Place, by President Ockerson. Twenty-one members and two visitors present.

The minutes of the 435th meeting were read and approved. The Executive Committee reported the doings of its 214th meeting, recommending the applications for membership of E. R. Fish and H. C. Meinholtz. They were balloted for and elected. The committee reported having extended the privileges of the club rooms to the visitors to the Convention of the American Gas Light Association, to be held in this city three days, beginning October 21st next.

The committee recommended that the invitation of Mr. E. C. Parker to visit Cupples Station be accepted, and the date fixed for the afternoon of Friday, 22d inst. On motion so ordered.

The committee reported the proposed agreement with the Electric Club for the care of its library without recommendation. On motion ordered that their proposition be accepted, and contract executed. On motion, the Executive Committee was directed to have all the books under the care of this club insured.

The Special Committee on Convention of the American Society of Mechanical Engineers recommended that the club appropriate $150 from its treasury to the

Entertainment Fund. On motion so ordered. On motion ordered also that the secretary extend to the Convention the privileges of the library during their coming Convention.

On motion ordered that the thanks of the club be extended to Messrs. Robert Moore and R. E. McMath for valuable donations to the library.

The secretary read a letter from John C. Trautwine, Jr., asking the club's consideration of a bill now before Congress to establish engineering experimental stations. On motion ordered that the matter be referred to Prof. J. B. Johnson for investigation and report.

By request, Prof. Johnson then read an abstract of Mr. J. W. Woermann's paper on "The Construction of a Low Crib Dam Across Rock River." The paper was illustrated by numerous photos and blue prints. This dam is one of the structures of the Illinois and Mississippi Canal, known as the "Hennepin Canal," and is intended to furnish slack water navigation in Rock River above the lower rapids. The exact location, design, methods of construction, foundations, material used and the cost of the work, were fully given, together with a statement of the force employed and the time required to do the work.

Prof. J. H. Kinealy then described a form of planimeter which could be made of a single piece of wire, showing the methods of operating it, and principles upon which it was based. Under certain limited conditions of service, and if used with great skill, quite accurate results were possible. After considerable investigation and study Prof. Kinealy had worked out the mathematical theory of the instrument.

The discussion was participated in by Messrs. Harrington, Dunaway, Ockerson, Baier and Freeman.

The president announced that there would be no meeting on 20th inst., as the American Society of Mechanical Engineers would then be in session. Adjourned.

WILLIAM H. BRYAN, *Secretary.*

Montana Society of Civil Engineers.

THE regular monthly meeting of the Montana Society of Civil Engineers was held Saturday evening, May 9, 1896. The meeting was called to order by President John Herron. There were present C. W. Goodale, F. J. Taylor, Finlay McRae, A. S. Hovey and F. J. Smith.

The minutes of the previous meeting were read and approved.

Messrs. Taylor and McRae were appointed tellers to canvass the ballots for admission to membership. The result of the count being announced, the president declared that Mr. Abram L. Jaqueth had been elected a member of the society.

Senate Bill No. 2301, which provides for the establishment of engineering experiment stations, after being read and discussed, was, on motion, referred to Prof. A. M. Ryon, who, as a committee of one, was directed to investigate the merits of the Bill and to report at the June meeting.

It was voted that a committee of three be appointed "To look after legislative nominations." Messrs. McRae, Goodale, and McNeill were selected as members of this committee.

Mr. Finlay McRae was elected trustee, by acclamation, to fill the vacancy caused by the resignation of Mr. W. A Haven.

Adjourned.

FORREST J. SMITH, *Secretary.*

The Civil Engineers' Club of Cleveland.

Meeting, held May 12, 1896.—President Howe in the chair. Present 60 members and visitors. The minutes of the last meeting were read and approved. Messrs. Paul and Brown were appointed tellers to canvass the ballots for new members. Mr. Searles reported progress for the Committee on Association of Cleveland Scientific Societies.

The paper of the evening was then read by Mr. E. A. Sperry. It was entitled "Steam Engines for Direct-connected Electric Generators," and described his invention by means of which the Generator makes two revolutions at each stroke of the engine.

The discussion which followed was participated in by Messrs. Newman, Herman, Cowles, McGeorge, Dodd, Warner, and others.

Mr. Mergatroid presented some interesting facts in regard to the development of Rotary Engines and Steam Turbines.

The President announced the receipt of two more papers for the year's program: by Dr. D. C. Miller, May 26th, on "Phenomena of Electrical Discharges in Vacuo," illustrated by apparatus; and by Mr. W. R. Warner, October 13th, on "Modern Construction of Scientific Instruments."

The President then announced the election to active membership of Messrs. R. L. Newman, S. W. Hayes, A. M. Waitt, C. O. Arey, and W. B. Cowles; and the election to associate membership of Messrs. W. J. Walker, S. B. Sheldon, H. P. Fairfield, and Wm. Secher.

The Club then adjourned, and the members repaired to the neighboring restaurant where a lunch awaited them.

F. A. Coburn, *Secretary.*

Meeting of the Civil Engineers' Club, Club Rooms, May 26, 1896.—Vice-President James Ritchie in the chair. Present 85 members and visitors, including many ladies.

Reading of the minutes of the previous meeting was dispensed with. Dr. D. C. Miller read a paper on "Phenomena of Electrical Discharges in Vacuo," describing and experimentally illustrating the researches of Geissler, Hittorf, Crookes and Roentgen. The discovery of the X-rays was demonstrated, and the various theories proposed to account for the phenomena briefly explained.

The practical applications of the X-rays were explained with the aid of the fluoroscope and lantern projections.

After the meeting the company availed themselves of the opportunity, by the aid of the fluoroscope, of seeing the bones of their hands and wrists.

A light lunch was served.

F. A. Coburn, *Secretary.*

Association of Engineering Societies.

Vol. XVI. JUNE, 1896. No. 6.

PROCEEDINGS.

Boston Society of Civil Engineers.

Regular Meeting, May 20, 1896.—A regular meeting of the Society was held in Chipman Hall, Tremont Temple, Boston, at 8.15 o'clock, P.M., President George F. Swain in the chair. Number of members and visitors present, including ladies, 318.

The record of the last meeting was read and approved.

Messrs. Bertram Brewer, Emory A. Ellsworth, Charles F. Fitz, Jr., Edward I. Marvell, Lester W. Tucker, Frederic A. Wallace and William Wheeler, were elected members of the Society.

Mr. Fred Vincent Fuller was then introduced and gave a very interesting description of a recent trip to Mexico under the title of "One Month in Aztec Land." The paper was fully illustrated by lantern slides.

Adjourned. S. E. Tinkham, *Secretary.*

Engineers' Club of St. Louis.

437th Meeting, June 3, 1896.—President Ockerson called the Club to order at 8.35 P.M., at 1600 Lucas Place, eighteen members and four visitors present. The minutes of the 436th meeting were read and approved. The committee to whom was referred the bill to establish engineering experimental stations throughout the United States, reported as follows:

"*Engineers' Club of St. Louis:*

"Gentlemen:—The attached bill provides for giving to each State and Territory $10,000 a year, this sum to be increased by $1,000 annually for fifteen years, until the sum amounts to $25,000 a year for each State and Territory, and to remain at this figure thereafter, for the purpose of providing for engineering experiments in these several States and Territories. In other words, upwards of $1,250,000 annually is to be donated by the general government for engineering experimentation in about fifty different laboratories, most of which are now, and would remain, in relatively incompetent hands.

"There is now expended for experimental work on the strength of materials, at the Watertown Arsenal, the sum of $10,000 per annum, and this small amount has

proved sufficient for many years to maintain that work on a high plane of accuracy and efficiency. It seems hardly possible that the proposed large sum could be profitably spent in fifty different educational institutions, with anything like an adequate return to the cause of scientific experimentation. If engineering experiments are carried out by inexperienced and incompetent persons, and the results published by the general government, as is here proposed, these results are likely to be more or less erroneous and misleading, and might prove to be of more injury than benefit in engineering practice.

"In the opinion of the undersigned, this bill is an example of many that are now urged upon Congress which are consistent only with a more highly paternal form of government than ours has yet become.

"It is recommended, therefore, that no action be taken on this bill by the Engineers' Club of St. Louis. Respectfully submitted,

"J. B. JOHNSON, *Committee*."

On motion, ordered that the report be received and adopted.

The Secretary then read the following letter from the Secretary of the American Society of Mechanical Engineers:

"*Engineers' Club of St. Louis:*

"GENTLEMEN:—The American Society of Mechanical Engineers, at a session held just previous to the adjournment of its most successful St. Louis Convention, passed unanimously the following resolution:

"*Resolved*, That the hearty thanks of the Society be tendered to the Engineers' Club of St. Louis, and especially to its honored President, Mr. J. A. Ockerson, for the courtesies extended to the Society in the tender of the use of its comfortable house and valuable library during our stay in the city.

"You will permit me to add a personal expression of the indebtedness of the Society to the Club for attentions which it is not possible to recognize in formal and public resolution. Be assured, however, that because of the very nature of this co-operation, which had so much to do in making our meeting a pleasant memory, that I venture to add a word of personal recognition to the Club and its members individually. Very truly,

"F. R. HUTTON, *Secretary*."

On motion, it was ordered that the Secretary extend the thanks of the Club to the Cupples Real Estate Company, Capt. Robert McCulloch, and the Anheuser-Busch Brewing Association, for entertainments and courtesies extended on the afternoon of Friday, May 22d.

Mr. F. B. Maltby then read a paper on "Methods and Results of Stadia Surveying," treating the subject from the standpoint of a wide practical experience. He went into the details of the work at some length regarding the appliances necessary, force required, necessity of sketching, speed with which such work could be conducted, and the cost of same, showing some charts from actual service. Mr. J. L. Van Ornum contributed a written discussion which was read by Mr. E. J. Jolley. Messrs. Colby, Thomas, Turner, Jolley, Ockerson and Russell also took part in the discussion.

Mr. Julius Baier showed the Club a number of photographs showing the damage done by the recent tornado, and discussed it from an engineering standpoint. An informal discussion followed, participated in by nearly all present, after which the meeting adjourned.

WILLIAM H. BRYAN, *Secretary*.

438TH MEETING, JUNE 17, 1896.—President Ockerson called the Club to order at 8.35 P.M., at 1600 Lucas Place; twelve members and four visitors present. The minutes of the 437th meeting were read and approved. The Executive Committee reported the doings of its 215th and 216th meetings.

Mr. F. F. Harrington, of the City Testing Department, then read a paper on "Experiments on Vitrified Paving Brick." He called attention to the great variations

both in the methods of testing such brick, and in the specifications for same. A committee to look into this subject had recently been appointed by the National Brick Makers' Association, and as a number of engineers were on this committee, it was thought that their recommendations would be very generally adopted. Their investigation would cover the abrasion, absorption, specific gravity, crushing and transverse strengths, and hardness. The St. Louis Testing Department had recently made a series of investigations, with a view of determining the best apparatus and methods for conducting such tests. Special study had been given to the abrasion test by tumbler, to determine the percentage of volume which should be filled, the length of the tumbler, its speed, and the duration of the test. The speaker recommended that the tumbler be filled with brick to 15 per cent. of its volume, be run at the rate of 30 revolutions per minute, and that the duration of each test be 40 minutes. He did not approve of the use of cast-iron blocks with the bricks, preferring standard or unit bricks of known character and uniformity. The drying and absorption tests were also considered.

Messrs. Holman, Freeman, Flad, Kinealy, Wheeler, Crosby and Barth took part in the discussion. Mr. Holman explained a testing machine which he had just designed for the department. Adjourned.

William H. Bryan, *Secretary.*

Technical Society of the Pacific Coast.

Regular Meeting, June 5, 1896.—Called to order at 8.30 p.m., by President Dickie.

The minutes of the last regular meeting were read and approved.

Mr. A. D. Schindler, Civil Engineer, was elected to membership.

Upon motion that a Committee be appointed to represent the Technical Society during the stay of the American Society of Civil Engineers in San Francisco, the President, Mr. Geo. W. Dickie, and two Past Presidents, John Richards and C. E. Grunsky were chosen by unanimous vote.

President Geo. W. Dickie thereupon addressed the members present on a subject entitled : "Japan as seen through the eyes of a Mechanical Engineer," being an interesting narrative of observations made during the author's recent trip to that country.

The topic was freely discussed by a number of members present, Mr. John Richards making it the subject of a very intelligent argument on the economic questions involved in the development of Japan, as influencing the industrial condition of the United States.

The meeting adjourned until August 7th, the July meeting having been stricken from the yearly list by order of the Board.

Otto von Geldern, *Secretary.*

ADDRESS BY JOHN RICHARDS,

Before the Scientific Societies of San Francisco, in the Academy of Sciences, in honor of the Fiftieth Anniversary of Lord Kelvin's Professorship, June 8, 1896.

I have been assigned the honor of presenting some remarks upon the influence and contributions of Lord Kelvin in the field of thermo-dynamics.

A first inference was that such remarks should consist in a collection of history and facts in respect to Lord Kelvin's discoveries and explanations in dynamic science, but second thought showed that such a course would be tedious, both to prepare and to hear, also would be unnecessary.

There is nothing to be proved. The position Lord Kelvin holds at this time as an authority in the field of thermo-dynamics or the interrelation of heat, motion, force, and their resulting phenomena, is an accomplished fact, known and recognized in all civilized countries, and we may say by all men.

In this country, where he was selected as the chief of a commission to determine a scheme for the great power plant at Niagara Falls, his standing in the field of applied, and even constructive mechanics, is popularly known from that fact, while our technical journals for twenty years past have accorded him a measure of respect and admiration never before bestowed upon any one occupying a place in the field of useful learning.

The present, and hundreds of other meetings of the kind, held without respect to country, race, or distance, to commemorate Lord Kelvin's fiftieth year of continuous labor in one place and one direction and interest, is perhaps the most notable evidence that can be referred to of the present position of the natural and applied sciences, and the importance now attached to studies once thought immaterial.

The assertion of such sentiment is fitting and deserved in respect to Lord Kelvin, also is happily in contrast with national dissension and jealousy, now rife in some other fields of human interest.

The reasons for this tribute are found in several facts pertaining to the assiduous and unselfish labors of Lord Kelvin.

He is not eminent because of specific discoveries in physical science, or brilliant innovations of any kind. He is, as before said, rather an "explainer" and "harmonizer" of the diversified phenomena that rise so rapidly in our day as to drive other men into narrow channels, engrossing their powers in a single branch or subject. After fifty years, marked by a prodigious development in all the arts and sciences—a period inconceivable at the beginning and scarcely to be realized at its end—Lord Kelvin has become a mentor among men, occupying a position in physical research that Humboldt did in natural science.

This breadth of opportunity, while it permitted the play of genius, imposed a herculean task by its extent and diversified nature. Thirty years may be said to cover the history of thermo-dynamics as a computable branch of applied science. Previous to that time we proceeded by experiment and empirical rules, not wholly, but mainly; and the transition to the present state of this branch, beginning when Lord Kelvin was forty-three years old, must have since then occupied no small share of his efforts.

It is not easy to trace the course of physical research from the laboratory to the workshop. Such course is commonly devious and obscure. The original concept and its laborious evolution is lost sight of. Long before it reaches the machine or process that connects it with useful industry, the original work has disappeared or is regarded as of no importance.

It would be easy to supply striking illustrations of this fact and thus connect the name of Lord Kelvin with motive apparatus, manufacturers, transportation and other of the great agencies that make up the present industrial systems of the world, but, as remarked at the beginning, this is not called for on the present occasion, or before an audience like this, the purposes being, as I understand it, to offer

a tribute of respect to a man who has won a high position, universally conceded, and not requiring proofs at our hands.

For thirty years past his name has been directly or indirectly connected with almost every advance, and we must remember that long ago there was not even common acceptance or knowledge of the conservation of energy, or the correlation of forces, and that what now is common means at the hands of the engineer and mechanic, was then not existing, or locked up in treatises inaccessible except to the learned.

To the genius of Lord Kelvin is added a charming personality, combative in a high degree, but evincing only earnestness and sincerity, with due deference and respect for the opinions of others. His course in scientific research illustrates in that field, what his countryman, Thomas Carlyle, achieved in ethics.

There is indeed analogy between the two men in some respects; but William Thomson had to deal with stubborn facts and figures that would prove themselves, while Thomas Carlyle enjoyed the license of imagination and could mix up with his philosophy, opinions that did not require to be expressed in equation.

It will be no disparagement of Lord Kelvin to mention the fortunate environment and opportunities that have attended on his career; opportunities that our country does not afford at this time, but which may be reasonably expected in future among a people so intensely practical, because on all hands there is evidence that education and effort are being especially directed to the natural sciences, and this must in the end lead in the National economy to some form of recognition for those who, like Lord Kelvin, set out to work in the interests of all men, and of human progress, irrespective of nation, creed, or race.

It is a pleasure to feel there is one plane on which people of all nations can meet in the spirit of a common cause, divested of jealousy and that false patriotism that denies the fraternity of civilized people--the plane of science. This feeling, one of the noblest of human attributes, coupled with the interests of commerce, are almost the only forces that restrain people from the barbarism of war.

I cannot remember that Lord Kelvin has ever directed his energies to the improvement of implements for destruction. It is scarcely conceivable that he would do so in the absence of logic or philosophy for killing people and destroying property to determine problems of international polity as they arise at this day. I am proceeding on inference in this matter, and in the thought that next to being an expression of regard for Lord Kelvin's labors, the principal fact of this meeting is its international or denational character.

Thermo-dynamics being closely allied with the mechanic arts, and consequently with commercial interests, cannot claim the liberal nature of some other branches. Foremost in this spirit is the medical profession. It is strange that there is scarcely one among those who have in recent times risen to eminence in scientific research that have not taken a medical degree at the beginning of their career. Liebig, Huxley, Mayer, Leibnitz, Faraday, Tyndall, Helmholtz and Thomson, have all, as I believe, drawn inspiration from the universality of medical science.

This admission, we of the useful arts are glad to make, pointing out, however, that the example of Lord Kelvin's career shows the unselfish nature of all scientific pursuits by men of broad views and intelligence to see the interdependence of all human interests.

The product, to so call it, of the University of Glasgow is a national anomaly. Out of the bigotry and intolerance of Scotland in the seventeenth century, came

advanced and liberal ideas in both science and economics in the nineteenth. In 1776, Adam Smith published the "Wealth of Nations," which Thomas Buckle claims has influenced the affairs of mankind more than any other book, the Bible alone excepted.

Circumstances point to a revulsion there against what was not proved or provable, and the exact sciences took root in that old school at Glasgow, producing among many other men of eminence, most notable of all, the one in whose honor this meeting is held.

The Civil Engineers' Club of Cleveland.

MEETING of the Civil Engineers' Club of Cleveland at the Club rooms in Case Library, June 9, 1896. President Howe in the chair.

The minutes of the last two meetings were approved. The application of Mr. Virgil G. F. Marani, for admission to active membership, was read. Messrs. C. W. Hopkinson and C. O. Palmer were appointed tellers to canvass the ballots for membership of Elmer A. Sperry.

Dr. C. O. Arey then presented the paper of the evening upon "Water Supply and Sewerage as affected by the lower vegetable organisms."

The Doctor in his exhaustive and interesting paper considered the subject in sections, as follows:

(1) Water contains few bacteria that are harmful.

(2) All water contains forms of life that destroy bacteria.

(3) Sunlight destroys bacteria.

(4) Water will purify itself when the source of contamination is removed.

(5) Sewer-gas alone is not dangerous to health.

(6) The effect of disease organisms upon water supply and upon sewage disposal.

He showed how imperfect were ordinary filters as precautions against the germs of disease in water; how they served as breeding-places for the same under the usual conditions and management; how little reliance could be placed upon the clear, sparkling appearance of drinking-water as an indication of its purity; and how difficult it was to avoid the germs of disease. On the other hand, he also testified to the little danger incurred by a healthy person in drinking-water as it is usually found; and how little danger there was in the ill-smelling sewer-gas.

Interesting questions from Messrs. Warner, Hopkinson, Porter, and others brought out many facts that showed the errors of current notions in regard to danger from typhoid and cholera germs.

The discussion also brought out the fact that there is no efficient inspection or means provided to prevent the use of the public sewers of this city for typhoid or cholera infected excretia.

The President announced the election of Mr. Sperry. The members of the Club then adjourned to the restaurant.

F. A. COBURN, *Secretary.*

JOURNAL

OF THE

Association of Engineering Societies.

BOSTON. CLEVELAND. MINNEAPOLIS. ST. LOUIS.
MONTANA. ST. PAUL. DENVER.
VIRGINIA. PACIFIC COAST.

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ABBREVIATIONS.—P = Paper; = D Discussion; I Illustrated.
Names of authors of papers, etc., are printed in *italics*.

ASSOCIATION
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PRINCIPLES GOVERNING THE DESIGN OF FOUNDATIONS FOR TALL BUILDINGS.

BY RANDELL HUNT, MEMBER OF THE TECHNICAL SOCIETY OF THE PACIFIC COAST.

[Read before the Society, April 3, 1896.*]

THE modern tall building is in many respects a good personification of our national character. Utility first and foremost, adaptability to immediate surroundings, and a capacity for acquiring the "almighty dollar" with ease and certainty.

It is "all things to all men"—convenient to commerce, comfortable and healthy. Professional and business life within its walls is not worried by the little annoyances which in ordinary surroundings are apt to detract from the more serious pursuit of material happiness.

ORIGINATED IN CHICAGO.—It is not surprising then that Chicago, most typical of all the cities of our national characteristics, should have been the place where these wonderful structures have received their greatest development. Nor was it cause for astonishment when it was discovered that the soft, muddy subsoil of this city precluded the use of the recognized methods of founding ordinary buildings; that a new and distinctly original solution was applied to give a safe and permanent support to the towering structures.

It can hardly be said that this result was achieved at once for any one building, for the true underlying principles of all foundation work were rather forced upon the builders and designers by a series of mishaps, which demonstrated in a most practical manner that scientific principles are the only true and safe ones to follow.

* Manuscript received May 4, 1896.—*Secretary, Ass'n of Eng. Socs.*

Necessity of providing for settlement under certain conditions.—If a particular soil will support but a limited weight without compression and settlement, then one must make suitable provision for such change in the position of the base, which of necessity must occur in any structure founded upon it, and exerting a pressure beyond that amount it will carry without any yielding.

In the case of a building certain principles of construction have been recognized as necessary—when it is founded upon a compressible earth—to prevent unsightly cracks and sometimes dangerous results from occurring.

To keep the area of the base of the building so large that the pressures transmitted to the earth will cause no settlement whatever is often regarded as impracticable, and in many localities it has been found that after a certain limited compression of the soil has taken place no further settlement need be apprehended.

This at least is, and has been, the argument in some places where many of the largest and most costly of our modern buildings are being erected.

Method of independent piers.—The method of founding large buildings upon independent piers is one now so common and so well understood by engineers and architects as to hardly call for any particular explanation here. It is simply a recognition of the well-known fact that if a beam is acted upon by two forces at or near its ends it tends to assume a curved form due to the unequal moments of the pressures transmitted to the beam from the reactions of the ground upon which it rests.

Fig. 1.

If this beam, as in the case of masonry connecting walls, is weakened by numerous openings, as windows or doors, one above the other, or by any other means, so as not to have sufficient strength in itself to transmit the pressures on its ends to the ground beneath throughout its entire length without deflection from reactions, then it will bend or crack on the lines of least resistance.

Uneven foundation pressures immaterial on rock.—In solid soils, or upon rock, or upon any perfectly unyielding foundation, it is immaterial, of course, how unevenly the pressures may be transmitted to it, and unless there is overloading to the crushing point, the principle of independent piers is of no practical use, excepting from an economical and perhaps convenient point of view.

DAMAGE FROM SETTLEMENT.—The upward reaction between the points of great pressure in a compressible soil usually results in a building being damaged by cracks extending from the base to the roof and following the line of windows from story to story.

COOPER INSTITUTE.—To illustrate briefly this common cause of failure in buildings, I have chosen as an example of the results which will happen from neglect of the principles just explained the Cooper Institute of New York.

This building was founded in 1853 upon piers carried down 22 feet below the sidewalk, and resting upon a continuous masonry footing course 1 foot 4 inches thick. In 1885 the settlement and consequent cracking of the walls had become so great that it was considered dangerous, and extensive reconstruction of the foundations was entered upon.

An examination of the building shows at a glance that the chief weight of the walls is carried down the piers "A" and "B" to the foundations, and that the pier "C" between these two carries but a small weight in comparison. From bad proportioning of the footings of these main piers only a limited area was capable of receiving the full pressures, and as much as six tons per square foot was thrown on the foundation soil. Failure occurred by the continuous stone footing cracking across, and the main piers were shoved down into the overloaded earth, tipping up the outer edges of the stones directly under them, which were not continuous but jointed in the center. At the same time the intermediate pier, with its light loading, remained without settlement, and as the piers on either side sank the upward reaction was sufficient to cause a "vertical fraction at each side of every window from the third story down."

If all the footings of the piers had been properly proportioned, so as to have exerted a uniform pressure per square foot on the soil, and this had been well within its safe supporting power, there would have been no accident. But as this is at best a difficult thing to always secure, viz., a soil which does not compress at least a small amount, even with light loading, other methods of supporting the intermediate pier could have been adopted if unequal settlement was feared.

CHARACTERISTIC CONSTRUCTION OF MODERN HIGH BUILDINGS.—The modern high building consists, in most recent examples, of a steel skeleton frame from the foundations to the roof, in itself carrying all the weight, from story to story, of the masonry walls, partitions and floors. These walls are reduced to the least dimensions—to sustain themselves only—being merely "curtain walls" in most cases.

The basements are usually required to have plenty of light and as much or more openings than the stories above. Therefore the method

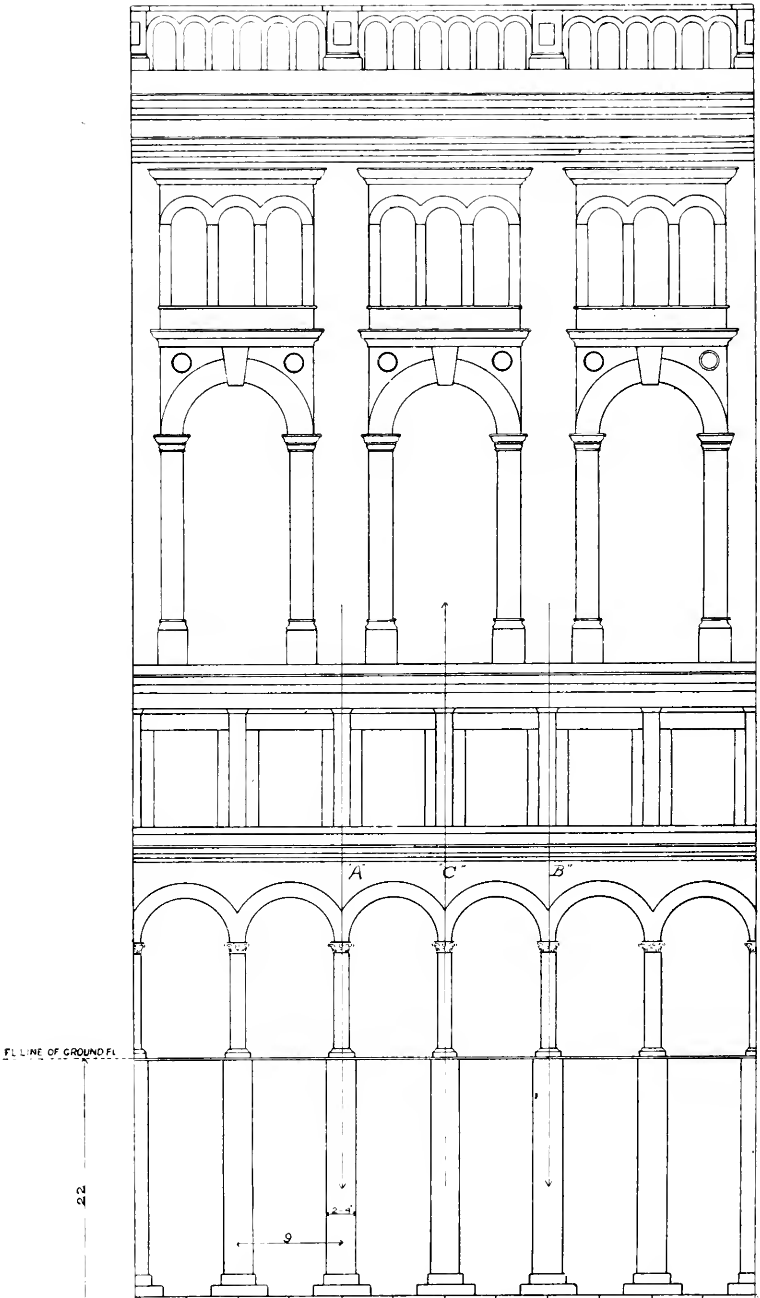

Fig. 2.—Cooper Institute, New York.

of placing each column, or pair of columns, upon its own base, separated and independent from the next set, becomes a very convenient method of economizing space for light and available area for business purposes.

Masonry piers under columns.—If there is plenty of good, hard ground underneath the level of the basement floor, the area of base necessary to be placed under each steel column could be easily attained by excavating to sufficient depth, so that a masonry pedestal could be built, with only the usual safe slopes or offsets from the bedplate to the ground.

If the foundation soil was very hard and incompressible—capable of carrying large loads, say of five to six tons per square foot—then the ground area required for the foundation piers would be small, and consequently they need be of but limited depth in the ground. But if, on the other hand, the supporting power of the soil is very small and liable to compression, reducing the unit of safe weight which can be placed upon it to from one to two tons per square foot, then it becomes necessary to have a foundation base of large area. This can only be accomplished by making the masonry pier of considerable depth down in the ground, so as not to exceed the proper safe slope or projection of the footing courses.

Advantages and disadvantages of this construction.—There is no objection which can be urged to this method of securing a foundation if the soil is a suitable one for the practical carrying out of the construction.

In fact it has many distinct advantages over the usual shallow steel beam and concrete foundation.

Unfortunately the conditions of the foundation sites in many of our large cities, as well as extraneous conditions, such as neighboring buildings, ground, water, etc., make this method at times more or less impracticable.

Founding upon a bed of firm soil overlying softer material.—In Chicago, for instance, the peculiarities of the ground formation make it entirely out of the question to found in the above manner, for almost without exception the records of the borings of the foundation sites of the large buildings show a depth of only from twelve to fifteen feet of a very moderately firm soil overlying a much softer clay subsoil of considerable depth.

The use of this top crust of firm ground, without in any way cutting down into it, has been the object sought by most of the architects and engineers in founding their large structures.

Origin of concrete and steel beam foundations.—Hence, as is usually the case, necessity became the mother of invention, and

steel beams in shallow piles, placed in tiers at right angles to one another, took the place of more bulky masonry, and attained the same purpose without requiring but very limited excavations.

Adopted by force of circumstances for peculiar conditions, yet the method of construction has shown itself to be more or less well adapted for other localities where these surroundings may not exist.

A great change in the relative cost of materials has also been another factor in the use of these foundations. Steel beams are almost 100 per cent. cheaper in cost to-day than fifteen years ago, and, in addition, their properties and use are better understood.

Mr. Bauman, an engineer of Chicago, called particular attention some years ago to the method of independent piers for foundations in compressible soils, and announced it as a scientific principle of construction, which was a necessity in soils such as in Chicago. He simply explained a very ancient foundation method in use since the times of of the Goths. It is certain, however, that the practice has followed on the lines indicated by him with more or less success.

Calculation of weights supported by independent piers.—If the lines of pressures on the ground area under one pier overlap those of a contiguous one it becomes necessary to make a single base for both piers. In this way there has developed a growing tendency in the later examples of large buildings to lessen the number of independent foundations by grouping several columns upon one base.

Undoubtedly independent piers, if very carefully proportioned to the exact weights carried upon their bases, as well as taking note of the friction upon their perimeters, offer a proper method of securing a foundation for tall buildings.

There are, however, certain principles not so easy to calculate in definite terms, which introduce more or less difficulty in arriving at a correct area to give the bases of columns transferring very unequal weights.

It is a known fact that large areas of soft soil will not support the same weight per unit of surface as more limited areas of the same soil.

It becomes necessary in designing the bearing area of the base of the foundations to take into consideration this fact if one is to feel perfectly certain of an equal settlement of all the piers.

An equal allotment of weight to be supported per square foot of ground area, under small piers as well as under much larger ones, will certainly result in an unevenness of settlement due to this principle just enunciated.

Chicago practice is the result of experiment.—Before the era of extremely tall buildings—some twelve years ago—various methods of founding in that peculiar soil had been tried. The more common

practice of to-day is largely the result of actual experiment and successful precedent. Still one cannot but be impressed with the fact that there is not a uniformity of opinion that correct methods have yet been adopted. One is startled to know that buildings which have cost one and a quarter to one and a half millions of dollars, are expected to, and do, settle five to six inches during the first year or two of construction.*

The floating of such buildings upon a crust of soil but twelve to fifteen feet thick, overlying a softer watery clay, shows a reliance upon future stability which is sublime, and entirely Chicagoan in its assurance.

INVESTIGATION OF THE DIRECTION OF THE GROUND PRESSURES.—If reliance is placed upon the strength of a top layer of soil which overlies a weaker material, then an investigation should be made to determine if the foundation pressures are distributed over a sufficient area of the lower soil to be within its safe bearing capacity.

It was at one time thought that the angle which the direction of the pressures through the ground made with the vertical was equal to the natural angle of repose of the material.

Experiments—in sand particularly—would seem to indicate that this is not correct, and that the angle is really about one-half the slope angle of the earth.†

Let the Fig. 3 represent the foundation of a column in a building resting upon sand. The angle of repose of ordinary moist sand is about 40°, in which case the angle of pressures becomes 20°; therefore the dimensions of the ground area which receives the original foundation pressures can be easily investigated at any depth.

Supposing a strata of soft clay, or other material, to exist, then by drawing to sufficiently large scale the figure herewith shown, one can easily measure off the dimensions receiving the pressures and see if the load per unit of area is within the safe pressures which is permissible on soft clay.

Let $\Phi =$ the angle made by the direction of the pressures, and this is equal to one-half the natural angle of repose of the soil.

Then the width of base b', which receives the foundation pressures at a depth h, is:

$$b' = b + 2\,h \tan \Phi,$$

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* The Monadnock Building, nearly 200 feet high, with a pressure on the foundation soil of 3,750 pounds per square foot, settled very uniformly five inches.

Old Colony Building, 215 feet high, with 3,220 pounds per square foot on foundations, in nine months settled from $4\frac{3}{16}$ to $5\frac{1}{8}$ inches. Both these buildings are considered successful examples of Chicago practice.—*Engineering News*, October 13, 1892.

† Handb. d. Ingen. Wissensch., Bd. II, p. 196. Wochenbl. d. Ver. deutsch. Ingen., 1882, p. 53. Experiments by Brenneke and Forchheimer.

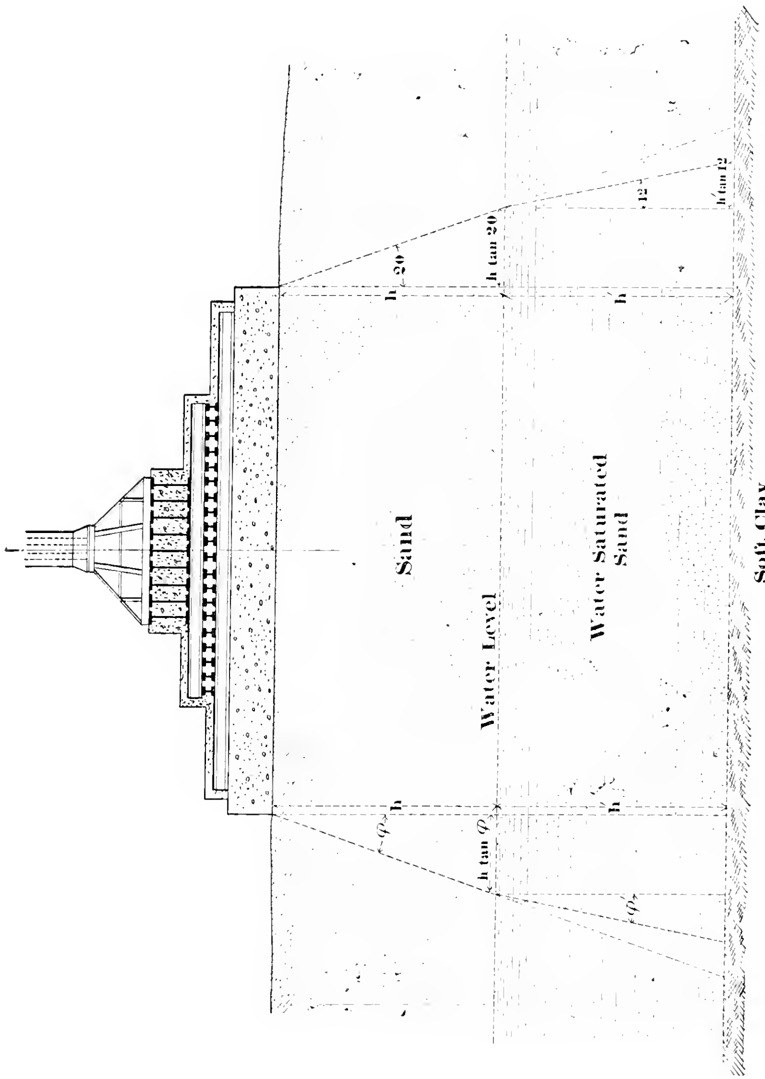

Sand
Water Level
Water Saturated Sand
Soft Clay
h
20
h tan 20
12
h tan 12
φ
h tan φ

FIG. 3.

in which $b =$ the width of base of the foundation pier at the surface. At a depth of $h + h'$ the width of base b_2 is equal to

$$b_2 = b + 2h \tan \Phi + 2h' \tan \Phi',$$

in which Φ' represents a change in the angle of pressure direction due to a water-soaked material, which has a much smaller angle of repose than the same sand above the water level.

If the area of the soft clay at this depth is not sufficient to give a value per unit of surface less than its safe supporting power, then the dimensions of the base of the column must be increased.

In addition, one must take into consideration the weight of the earth itself which lies between the base of the foundation and the strata of the soil considered.

NARROW LIMITS OF PRESSURES IN WATER-BEARING GROUND.—The natural angle of repose of water-soaked soil becomes very much less than when dry or simply moist.

The very common condition in the foundation of a building is that the level of the ground water is within a few feet of the base; therefore, although the angle of the pressures of the foundation may commence, when the ground is dry, to extend itself over considerable area, yet, as soon as the water level is reached, this angle becomes very much less.

For sand, the natural slope, when water-saturated, is about 24°, and this would limit the pressure directions to only 12°, as shown in Fig. 3.

In reality, the natural slope of repose of the earth under a foundation base is not capable of too close an analysis. It is undoubtedly affected by depth, degree of moisture and the lack of uniformity in the character of the soil. Yet an investigation can usually be carried out on the lines which have been suggested, so as to leave no doubt as to the limiting thickness which a top crust of soil ought to have, to properly distribute any weight placed upon it, to a weaker subsoil.

EARTHQUAKE EFFECTS.—Vibrations are more or less injurious to all structures, and good construction seeks to reduce them to a minimum. The relationship of the foundation of a building to its superstructure is of much importance in this respect, and in any country subject to earthquake shocks due regard should be paid to avoiding their effects.

Careful investigation in Japan, extending over many years' observations, as well as in other earthquake countries, shows that unless the locality is situated directly over the center of the disturbance there is seldom any damage to well-constructed substructure work.

In certain portions of South America so well is this understood that the lower stories of the buildings, while of heavy masonry, or adobe, will have pliable basket-like construction in the upper stories.

The movement of an earthquake is vibratory, and in those parts of the

United States in which they have occurred the amplitude of the vibrations is comparatively small, so much so that well-constructed masonry in considerable mass in the ground is capable of taking up the oscillations without damage.

The greatest intensity of the shock and the amplitude of movement is at the beginning, rapidly diminishing during its duration, much like the vibration of a tuning fork, or like sound-waves.

Therefore the oscillations of a foundation of a structure will be the same, and no more, than those of the ground in which it is built. The building above, however, may become subject to a cumulative vibration derived from the oscillating base, and this is the usual cause of disaster.

This is due to the fact that the vibrational period of the building itself, caused by the first shock, becomes a multiple of the earth vibrations, and the amplitude of them is thus increased, though in reality those of the earth are diminishing.

Such oscillations might throw additional strain on the foundations of a building, and from the existence of different vibrational periods in one part of a structure over another—if the building rested upon inde pendent piers—one or more of them might be called upon to carry greater pressure to the soil than others.

Steel buildings safe in earthquakes.—Before the days of recent steel skeleton structures, independent authorities in different portions of world, who were seeking a proper design for buildings which should be earthquake proof, recommended iron frame construction.

The idea being the building should be tied and braced together in all parts; that they should be light in weight as well as strong; that any vibration should be as a whole, and not greater in one part than in another.

The superstructure of the modern steel frame building complies with all these conditions, although no thought of earthquakes had anything to do with the general growth of the design.

Not so with the foundations however.

Movement of buildings during earthquakes.—The moment of inertia of a heavy overhanging roof, or top of a tall building, seeks to keep it at rest, and if the base is set in motion by a sudden shock, great forces occur tending to cause rupture between the foundation and the superstructure.

The building being strong enough to resist rupture at this moment of time, the great roof now moves forward, and the energy of its movement may be increased by coinciding with the vibration of the ground. It resists any sudden checking of its motion only by causing again strains to occur of the greatest magnitude.

How the foundations should be designed.— It appears to me that in a building of great height, in which, of course, the amplitude

of the vibrations at the top is extremely liable to be greater than at the base, that this base in all its integral parts should move as a whole, and no part of the foundation should be able to transmit an unequal movement to the superstructure.

Considerable mass and weight in the foundation will in itself take up and destroy part of the movement of the earth before transmitting it to a building upon it.

SHALLOW FOUNDATIONS NOT PROPER FOR EARTHQUAKE VIBRATIONS.— The method of independent piers, as now built in common practice, makes use of small mass and weight, and would transfer any earth movement in the quickest and most direct manner to the steel frame resting upon them.

Prof. Milne found at the college at Tokio, Japan, a difference in the intensities of the earth movements during an earthquake, even over a very limited plot of ground. For this reason it is certainly better to make a single foundation for a building, or one which must move as a whole. It has also been determined that there is less vibration at a depth of some feet in the ground than on the immediate surface.

Of course, in buildings covering very large areas of ground this becomes well nigh impracticable, or unduly expensive, but a continuity in the foundations should be sought to as great an extent as possible.

FOUNDATIONS SHOULD BE DESIGNED TO ACT AS A WHOLE.— If due regard is paid to the principle mentioned in the first part of this paper—to avoid throwing upward reactions upon connecting walls, or of transmitting shearing and transverse strains upon insufficient masonry construction—foundations can be so designed as to act as a whole, and without causing deformations or cracks in the superstructure.

SOLID MASONRY OFTEN CRACKED BY EARTHQUAKES.— In the earthquake which occurred a few years since in the Vaca Valley of California it was observed that less damage was apparently done to some of the older and more "flimsily" constructed buildings than to those of more firm and rigid masonry. This was due to the fact that the old buildings were loose-jointed, and simply separated and pulled apart in many places without uniform vibration as a whole. On the other hand, the firm brick walls cracked throughout their entire lengths.

This is in accordance with Prof. Milne's investigations in Japan. He says: "An important point, which constructors should keep before them, is to avoid coupling together two parts of a building having different vibration periods, or else to couple them together so securely that they shall move as a whole."* The trouble with the Vaca Valley buildings was, they had sufficient strength to gather great vibrations, but not enough to resist final rupture.

* Inst. of C. E., Vol. C.

Proportions to resist earthquakes. — Theoretically, the weight of a high building should decrease uniformly from the roof to the foundation. The weight of one story, as concentrated mostly in its floor system and in its exterior walls about the floors, should not be carried upon too slender piers to the story below.

Unfortunately the modern demand for light and space makes a very undesirable condition of affairs in this respect; in the first one or two stories above the foundation very often the ground floor is given up to shops, and nearly all the space which should be in walls or heavy masonry piers is converted into large windows and openings. The entire building over this floor is generally carried upon iron pillars. The vibration of the massive structure above them can only be transmitted to the foundation by means of these small columns, throwing a duty upon them which is most tremendous; and, in fact, they are unsuited to taking up these vibrations and transmitting them to the foundations and the ground.

The building does not vibrate as a whole, and cannot do so with this method of construction. And particularly in the modern structures of great height should attention be paid to this principle of providing mass and weight in the base, with the least possible amount in the top of the building. Between the roof and the foundation both mass and weight should be gradually proportioned without such open construction as to permit of the independent vibrations of different parts of the building.

Steel beams in concrete.—Concrete and masonry have not, as a rule, much transverse shearing or tensional strength. When used in foundation work it should be the aim to so proportion their dimensions and positions that they will be subject to compression only. Steel beams introduced into concrete do away with the deficient strength of the concrete alone and renders it safe for transverse strains. For this purpose this construction becomes most valuable in foundations, not the least of which is that the exact dimensions needed are susceptible of accurate calculations.

Magnitude and weight.—It is not wise, however, in many cases, especially when earthquake vibrations are liable, to make the foundations too shallow, simply because the steel beams in themselves may have sufficient strength to take the strains that come upon them, for the reasons which we have explained before, of providing a base of magnitude and weight to take up the vibrations transmitted through it.

In the first part of this paper I have mentioned the fact that there is no objection to foundations of masonry alone without depending upon an interior steel stiffening. What I mean by this is that such a foundation, proportioned mostly for compressive strains, requires considerable depth in order to secure sufficient area of base, and hence acquires large mass and weight. The considerations which have just been shown are

among the chief ones to prevent undue transmission of vibrations to a superstructure built upon them and to give great rigidity to the structure as a whole.

MONOLITHIC FOUNDATIONS.—I find numerous examples in German cities of successful monolithic concrete foundations under heavy buildings. But in all such cases the great thickness of the concrete is evidently relied upon to give sufficient strength to the base to resist uneven reactions. The Nicolas Church in Hamburg rests on a bed of concrete 8 feet thick, while under the tower this thickness is increased to 11½ feet. And other buildings are recorded with depths of from 5 to 6 feet.

In contrast to these the monolithic foundations of Chicago have generally failed. The City Hall settled very unequally, as much as 14 inches; but the bed of concrete under it was about three feet thick, and this appears to have been as great a thickness as was used in any of the other buildings upon such foundations.

A monolithic concrete foundation stiffened with heavy steel beams at right angles to one another, and not too shallow, makes an ideal system of construction, provided correct dimensions are given to the base.

FOUNDATIONS OF THE "CALL" BUILDING, SAN FRANCISCO.—The building now being built by Mr. Claus Spreckels, in San Francisco, and commonly known as the "Call" Building, rests upon a bed of sand. It is almost square, being 70 feet by 75 feet in plain dimensions. The foundation consists of a layer of concrete 24 inches thick, then a tier of 15-inch steel beams spaced 18 inches centers, and then another at right angles to this of the same dimensions, all void space being filled with concrete. On top of this solid platform rest 20-inch beams grouped together under the columns as shown.

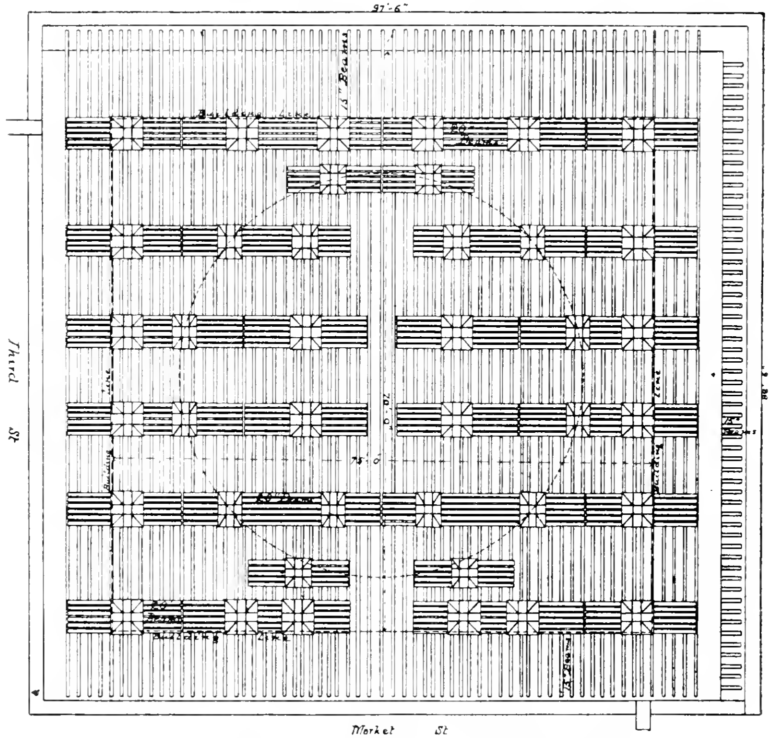
On the sides of the lot adjoining other buildings the steel beam and concrete platform is extended, so as to be used in supporting them. All beams are spliced, so as to be continuous from end to end. The outside columns are anchored to the foundation with two anchor bars of steel 1½ inches by 8 inches, which are fastened to the under side of the lowest tier of beams and extend up and into the columns themselves, to which they are riveted. Messrs. Reid Bros. are the architects for this building.

PILE FOUNDATIONS.—To us on the Pacific Coast it appears strange, in investigating the foundations of large buildings in other parts of the country, to notice the avoidance of piles as a means of founding.

Both in Chicago and New York the underlying hard pan and rock appear to be within the reach of long piles. At Chicago, firm clays appear from 45 to 50 feet from the surface, and the rock about 80 feet, while in New York the rock generally occurs in less than fifty feet.

The shock of driving piles next to other buildings undoubtedly has been one cause which has in some cases precluded their use; but it would appear that in Chicago it has been largely due to a distrust occasioned by the failure of several buildings founded on piles a number of years since. By the advice of several prominent engineers of late years a very few of the most recent buildings have been placed upon piles.

Piles make firm foundation.—Under the conditions of piles



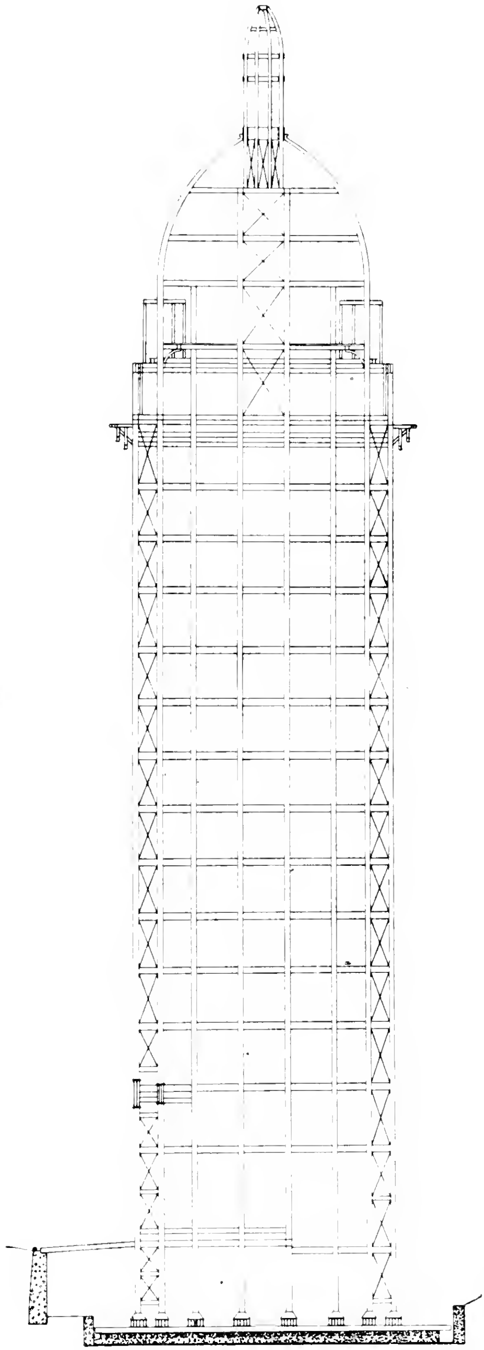
Plan of Foundation of the "Call" Building

Fig. 4.

being driven into a firm soil there is no better foundation, provided they are kept continually wet, and hence safe from decay.

When they depend entirely upon a small surface friction on their sides, as in our own shore mud and clays, we know even then that when driven to great depth they are safe for moderately heavy loads.

I desire to carefully avoid any discussion here of the very broad subject of the supporting power of piles, beyond the general statement that it is but a rare situation and condition of things when full and



SECTION OF THE "CALL" BUILDING, SAN FRANCISCO.

FIG. 5.

ample supporting strength cannot be secured by a properly driven pile foundation.

Should be driven deep.—If piles driven thirty or forty feet do not show sufficient resistance during driving, and the character of the soil is such that one does not care to risk its remaining with the same supporting power after a lapse of years, I can see no reason for stopping at this depth.

This is, and always will be, one of the chief causes of pile foundation failures, viz., the inability to recognize the proper depth to which piles should be driven. As I have said before, it is a very broad subject, and has many most interesting and abstruse matters relating to it, which would require an even longer paper than this one to make clear.

Grillages.—A grillage of timber on the heads of piles makes a most efficient base upon which to found a structure. In distinction from the very common method employed—largely in Europe—of placing concrete upon and around the heads of piles, it is the more usual American practice to build upon a timber grillage.

I think it is obvious, for the reasons stated before, that transverse breaking strains should be avoided in masonry of any kind; also because of a ready means of tying and bracing together in various directions all the piles of a foundation, and thus causing them to act as a unit for stresses of all kinds that the timber grillage is much the more preferable method of construction.

Cantilever construction.— A not uncommon condition of affairs, in designing the foundations for a tall building, often occurs in which it is necessary to keep entirely within the lot line and the outer line of the walls of the building with the substructure work. Under such circumstances it is difficult to avoid throwing undue strain on the outer edge of the footings. If the soil is a compressible one it is of the utmost importance that the center of the ground areas and that of the pressures transmitted to them should be concentric. In the case of buildings founded directly upon the soil this is often very difficult to manage satisfactorily, and in fact, under any method of founding, it is undesirable. In New York this problem has been met, in several notable instances, by the device of constructing the building upon the great steel cantilever beams, which overhang from tubular piers founded upon the solid rock, and placed entirely within lot lines.

By this means the center of pressure from the weight of the building can be transferred to the center of the foundation areas.

Broad base most desirable.—It is always better construction in any structure to found on a broad base, and no matter how firm a foundation may be secured, a great, tall building, two hundred or more

feet in height, resting upon a base, the exterior edge of which encloses an area smaller than the plan of the structure itself, is not in the most desirable condition of stability.

Of course such designing is not the result of choice, but from necessity.

FOUNDATION DIRECT ON SAND.—Of late years it has become somewhat more common practice in the city of New York to found some of the great buildings directly upon the sand, which is a natural formation there, while in Chicago there is an undoubtedly growing tendency to found upon piles driven into the hard clay, or upon wells excavated down to the hard strata in the soil and then filled with concrete. The practice in both places, by a process of evolution, is simply approaching correct theoretical principles.

SAND GENERALLY SAFE.—Sand, provided the same is not liable to future disturbance by nearby excavations, or from flooding or other causes, is, as is very well known, a particularly good foundation, and permits of loading with considerable pressures per square foot and with a minimum of compression.

The late distinguished engineer, Alexander Holly, boldly founded an important structure upon a quicksand, but first took the precaution to permanently enclose it.

FACTOR OF SAFETY FOR SUPPORTING POWER OF SOILS.—It is considered good practice, and entirely permissible, to strain up to 16,000 pounds per square inch on the steel beams used in tall building construction. This is about 50 per cent. of the elastic limit of the metal.

Why are not these conservative principles applied to the supporting power of soils in foundation work? Why is it more correct to load a soil which shows considerable compression and change in shape under a loading of, say 4,000 pounds per square foot, with a constant and unchanging pressure of from 3,000 to 3,500 pounds?

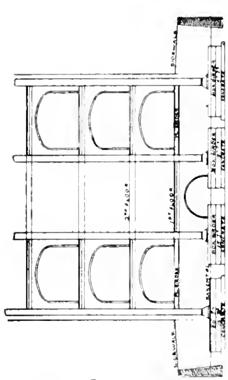
The author is satisfied that upon wet clay soils, or loam, or upon sand which is more or less impure, more moderate values of loading must be used than has been customary in the past in many of our greatest buildings.

MAIN PRINCIPLES.—The first and chief axiom in all foundation practice is to *know the exact character of the soil upon which the structure is to be built.*

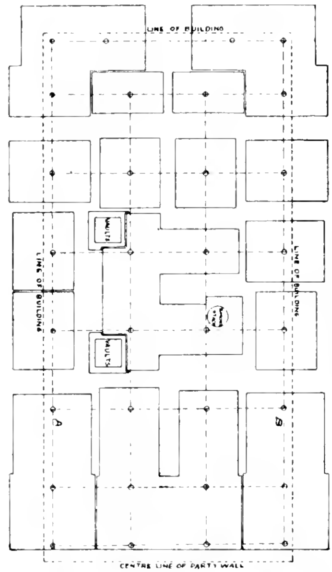
All other things become secondary to this great principle, and in fact resolve themselves into simple mechanical problems capable of definite solution.

All soils have certain safe supporting power, and are likewise susceptible of a definite amount of compression.

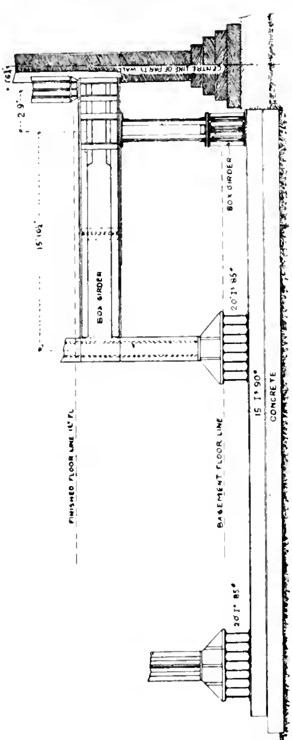
The loading of the same must be safe within the limits of such pressures as produce measurable settlement.



Cross-Section on Line A B.



Foundation Plan,
Old Colony Building, Chicago.



Vertical Section, Showing Cantilever.
Old Colony Building, Chicago.

Fig. 6.

The investigation of the soil must be complete for considerable depths and particularly is this necessary for pile foundations.*

Having acquired a true knowledge of the physical characteristics of the building site, the foundation design must be such as to recognize the various principles commented upon above.

Architecture is a science and art largely based upon historical precedent, but the foundation of a modern high building is a question of engineering construction. Excepting that precedent furnishes information with regard to the strength of materials it is a dangerous rule to follow blindly.

DISCUSSION.

Mr. Wagoner.—I would like to ask Mr. Hunt if the soil under the "Call" Building is sand?

Mr. Hunt.—I have been informed that it has a uniform sand foundation to a depth of forty feet or more.

Mr. G. W. Percy.—I have enjoyed the paper very much, and especially what was said about building foundations in Chicago. Some twenty-four years ago, just after the great fire in Chicago, I was engaged on some of the heavy buildings there, and I have a special interest in Chicago foundations.

At that time the system of building on isolated piers was just beginning to be recognized as the proper thing. It was very seldom practiced. It was the common practice there among the architects, when any science at all was used in building, to make the maximum load about one and one-half tons to the square foot. I was engaged in the office of the leading architects in Chicago. After the great fire they did a great amount of work. In a year and a half they put up a mile and three-quarters of street frontage of buildings to be used for office purposes, and these buildings ranged from four to seven stories high. This firm was then an advocate of isolated foundations, although they did not practice it, except on some of the buildings in which they were very anxious there should be no cracks or any marked settlement. In the Kendall Building, which is an office building of fire-proof construction, some of the boys from our office were sent there every month to take levels through the building, to see if any one part was settling faster than the rest. We figured on its settling about two inches,

* A most important bridge foundation failed in Philadelphia, because in the driving of the piles they were left with their ends just about to penetrate an unsuspected soft strata of mud. If a careful boring had been made beforehand it is needless to say the piles would probably have been driven deeper and the accident averted.

and that the pressure would be one and a half tons to the square foot. When it was found that any column was not settling as fast as the rest, pig-iron was taken into the building and placed upon that column until it settled equally with the rest. A large amount of pig-iron was used to bring about this result.

Something of the same nature was practiced on the Auditorium Building, I believe. The building was of uniform height and weight up to the base of the tower where it emerged from the roof. The weight of the tower above the roof was between three and four thousand tons. The architects loaded the foundations of the tower with about three or four thousand tons of pig-iron, representing the excess of weight of tower above the roof, and kept that load on the foundations until the entire building was up to its roof-line. Then as the tower was carried on higher they would remove the pig-iron from the base, the object being that when the building was at the line of the roof the weight was equal on foundation, and equal settlements should have taken place, and they removed the pig-iron as they added brick and stonework. So when the tower was completed it had no more weight upon the foundation than when at the roof-line. That was quite successful, but not entirely so. Some considerable settling took place at the tower, which the architects explain by claiming that some five hundred or six hundred tons were added by changes and alterations made on the tower.

I think Mr. Hunt has explained the real causes why these very lofty buildings settle so much more than the one and a half inches which used to be recognized as the proper amount of settling.

It is evident that, given a thick layer of clay, such as they have in Chicago, of seven or eight or ten feet thick, and a softer layer of clay under this, the ordinary style of building of five, six, and seven stories high, and a pressure of one and a half or two tons to the square foot, as the case may be, distributed over the entire area of the building, it was not sufficient to cause the entire strata to bend or yield, and therefore that the settling of the building was just the compression of the harder clay. But with these enormously increased loads of the high buildings the whole body of this upper layer of hard clay settles, and it is the lower strata that is overloaded rather than the upper one. I think that is a proper solution of it, because it is quite certain that an ordinary building of six, seven and eight stories in height, loaded to two tons even to the square foot, does not settle more than two inches or thereabouts, while some of these heavy buildings have settled five or six inches. I think this increased load is transmitted to the softer strata below.

In regard to the question of piles in Chicago, the reason given in those days for not using piles was that there was something peculiar

about Chicago clay which was not adapted to their use. In most places where piles are driven in mud or clay, and even where it is quite soft, when a blow will drive the pile two or three inches, if you let it stand six months and then apply the same blow, it will not move it; but in Chicago it is the reverse, and you strike a pile after it has been left this length of time and it will go out of sight. It is claimed that after the fire, buildings on pile foundations settled considerably.

In this city we have a very good hard sand, and there are many buildings where the foundations are loaded to about four tons to the square foot without any perceptible settling, not perceptible enough to make any cracks or dislocations.

I would take some exceptions to Mr. Hunt's remarks, as I gathered from what he said that he did not consider it best to load foundations so near the yielding point, and that the soil should not be loaded more than one-half of its elastic limits. I do not see that the argument applies to foundations. In the case of masonry, or most any material employed in buildings, there is a possible deterioration going on; but in the case of foundations there can be no deterioration; the foundations of sand under a building do not deteriorate with age, and the load may be very near to the point to which some yielding would take place. But if loaded double or treble that load, no serious consequences would result, therefore I do not see why it is not prudent and safe to load a foundation to near its yielding limit.

I would also make one other suggestion. The members of the Technical Society know I have advocated the use of twisted rods with concrete in foundations, and that I have made some experiments in this line. I make a uniform foundation, a platform for the building to rest on. This method is a great economy in materials as compared to some others. Take such a case as this: A platform of concrete, say 4 feet thick, with a sufficient quantity of twisted rods placed both top and bottom of the concrete, and one-fourth of the amount of steel in this foundation, would be equal in strength in every particular to a foundation where steel beams are put in.

Prof. Marx.—It may be of interest to know that Mr. Sooysmith, who has probably carried out more important foundation work in this country than any other engineer, is to bring this subject out at the April meeting of the American Society of Civil Engineers. I just happened to glance through a little paper which details the point he expects to bring out. Mr. Sooysmith calls attention to the fact that pile foundations in a number of instances have not been satisfactory, owing to decay of the piles due to a change in the subsoil water levels. The supposition was that the subsoil water level would remain permanent, but this supposition was found to be wrong. The piles are alternately exposed to water and air, and under these conditions of course they rot away.

In the matter of sand foundations Mr. Sooysmith mentions the fact that in New York City, in the case of large buildings built upon sand, such a method of founding is rather dangerous; that sand is a good material when confined, but that oftentimes when a neighboring building is torn down and a new building put in its place, the sand gives way to some extent, causing a subsequent settling of the building. Then the responsibility for whatever injury may occur falls upon the man who has erected the new building. He therefore suggests—and I think it is the method he has carried out—that the foundations be carried down to the solid rock by the use of pneumatic caissons.

I mention this as showing that the subject of foundations is interesting, and is agitating engineers at the present time.

Prof. Wing.—A question that comes up in regard to foundations composed of steel and concrete is that of the durability of steel in concrete. While it has been accepted that steel will last, that it is indestructible in concrete, yet I think there has been no definite determination of that fact, and it is not definitely known that the material will last. Observation of structures that have stood for some time I think points to the fact that it will last.

The plan of building on a continuous floating foundation under a building is one that depends upon whether the pressures of the building are uniform over the whole area or not. This inequality of pressures in the case of the Chicago buildings is corrected by giving each column a bearing area under it proportioned to the load it carries. As I understand the matter, they carry out this design so completely that where two foundations of concrete meet they separate them by a board, so there shall be no communication between the two foundations, thus preventing the concrete under two columns from acting as a beam and producing eccentricity of pressure on the foundation bed.

Mr. Percy.—I want to state another interesting fact about the foundations of the Post Office in Chicago. The matter created considerable discussion at the time the foundations were put in. It has been referred to very frequently as a failure of continuous foundation. I had an opportunity of observing the way it was put in. If I remember, the concrete was supposed to be four feet thick over the entire area of that great building. I watched the process of putting it in through the cracks from time to time. There was a layer of six inches of broken stone laid down, and then cement grouting poured over it; then another layer of stone six inches thick, with cement grouting, and so on. The papers spoke of it as the most perfect method of laying concrete that had been devised. The result has been that the building has settled, and there are cracks in the building in some places two inches, in other places eight inches wide, and in some places perhaps more; there has even been a breaking of columns and beams throughout the building.

PROF. SOULÉ.—I would like to have Mr. Hunt, or any other gentleman in the room who knows, state what has been the amount of settling of the Appraisers' Building here in San Francisco. You remember its foundation is a thick layer of concrete. I suppose some of you saw that construction. I believe the concrete is spread over a larger area than the building stands on. I think the concrete is about six feet thick. Of course the building is a heavy brick structure. I have been told that the settlement has been considerable, but as far as I know it has been pretty uniform over the whole area. I fancy if the weight of the building itself had been evenly distributed over that concrete slab, that with the thickness and weight of the slab itself the building would have settled uniformly. There was a discussion at the time as to whether the Appraisers' Building should rest on piles, as does the Post Office Building next to it, or on a concrete slab. The latter plan was adopted, I believe, by the late Gen. Alexander and Col. Mendell.

With regard to pile foundations I think that sometimes after long periods of time unequal settlement occurs in the building, due to a different cause from those mentioned by Prof. Marx. In Venice a great many buildings stand on piles driven in the mud of the islands of the archipelago; they were put up from the year 800 to 1000, and so on to 1200, during the period of the glory of Venice. Some of the heaviest buildings there were erected, I think, about the year 1200 or 1300. From an examination of some of those I am satisfied that while unequal settlement in some of the buildings has caused them to lean over in a rather dangerous way, in fact in some places to threaten to fall down if unsupported by their neighbors, the settlement has been caused in some instances by unequal weights on different portions of the piling, while in others I am very sure (and I draw this conclusion from personal observation) that the settlement has been caused by the long continued weight upon the piles, causing an actual telescoping of the fibers one into the other; in other words, an actual shortening of the piles through the cellular spaces being diminished. I saw in some places evidences of the piles having been compressed in the direction of their length to a considerable degree.

In our pile foundations, if we expect them to endure heavy loads for hundreds of years, the question of a thorough equalizing of the load coming upon the piles would, I think, be quite an item in affecting the final stability of the structure.

MR. PERCY.—I would like to say one word in answer to Prof. Soulé's question. The foundation of the Appraisers' Building was put in before I came here, but when I arrived the building was not finished. I am acquainted with the superintendent of the cement work, and he told me what would indicate a dangerous condition of the foundation. There

was a great body of concrete laid over the entire area, and at the north end it was resting on rock, while the other end was resting on soft mud, which, of course, we all realize to be a very dangerous condition. I have watched the building to see if there were any cracks from settling. There are one or two small cracks on each side, showing some movement, but nothing of the extent that would be expected under such conditions as this superintendent described to me. I think the Appraisers' Building has stood very well, and there has been very little movement of the foundation.

In regard to pile foundations and the capping of piles I would like to hear some further discussion. Instead of simply capping the piles with timber I am strongly in favor of digging around the piles six inches below the tops of the piles and ramming concrete all around the piles. In this way we get a full bearing upon the piles, and in addition to that we get the bearing capacity of the soil, whatever it may be; it binds the piles together as well as any grillage could do, and it is much cheaper. On the whole, I think the advantages are in favor of capping with concrete.

Within the past six months I have put up a building in this city alongside of a building resting on piles. I went below the foundations of the building, and I was curious to see what sort of bearing the building had upon the piles. I dug about the cappings, and I found places where I could push my rule in between the caps and the tops of the piles. The building had not been loaded heavily enough to bring the capping down. The piles were not cut off on an exact level line, and therefore the grillage did not rest on them properly. But in using concrete the way I have described, every square inch gets a bearing, and, to my mind, it is better than grillage.

Mr. Hunt.—The discussion has followed pretty near the lines I thought it would. I have been somewhat disappointed that nothing has been said in regard to the earthquake vibrations. There are only a few points that I would like to answer.

With regard to Mr. Percy's remarks about a foundation made of twisted steel rods in concrete, placed near the top and bottom, there is no criticism whatever to be made. The construction is exactly in line with the proposition I tried to bring out, namely, that when a continuous foundation is placed under a building it should act as a beam from one column to another, and the foundation must be of sufficient strength to allow this.

When the foundation is made entirely of concrete it should be made in the very best manner and of very great thickness. Not doing this has resulted in failures and results that were not satisfactory.

Prof. Wing alluded to the principle, used in Chicago, of separating

the foundation. I have here a drawing of the Old Colony Building, which is twenty stories high. The foundation plan shows the method of keeping the foundations entirely separate, even when the concrete bases extend close to each other. All the concrete areas have a distinct line of separation between them. This idea, when first started in Chicago, was used to such an extent that every single column had its own independent foundation, and with great care they kept them separate. Now they have commenced to group them more or less together.

The great Manhattan Building in New York, one of the highest of buildings, is constructed on a foundation in accordance with the ideas of Mr. Sooysmith, as represented in the paper he will present to the American Society of Civil Engineers, alluded to by Prof. Marx. His argument is on the line I have introduced here with regard to vibrations, only he had no reference whatever to earthquakes. It is that all buildings are subject to vibrations, however small, and sometimes they create considerable disturbance. Even the running of a hoisting donkey engine in the construction of a building causes vibrations that result in a settling of the building, The driving of piles will cause damage to adjoining buildings.

Prof. Wing.—I think my remarks in regard to building a continuous foundation have been misunderstood. Take a building like the Auditorium Building in Chicago, having a large tower in one portion of the building, and the other portions being of less weight and of less height, provided the foundation cannot cover a greater area than the building, if the building is constructed on a continuous foundation, there will be an inequality of pressure, and provision must be made for settlement where conditions like those met with in Chicago exist. In some cases the cantilever construction has to be used, as illustrated in Mr. Hunt's paper. If the building is simply of square construction, of equal weight in all portions, and of uniform height, I can see no objections to the plan of putting under a continuous foundation.

Mr. Hunt.—I am not an especial advocate of platform foundations, excepting when the conditions are favorable. I see no objections to this class of foundations in certain cases, and think they have distinct advantages. Of course, in a building of the size of the Mills Building in this city, it would be impractical to put it on a platform foundation covering the whole area. But the point I have tried to bring out in the paper is that the pressure upon the soil should be such that practically there would be no settlement. We know that all soils will support a certain amount of weight without compression, but they should not be overloaded. That is the principal point in all foundation practice; it is the underlying principle. It makes no difference if the foundation is upon soft mud, if we only establish the point of how much load it will carry without compression. The soil should not be overloaded.

Under certain conditions, where it would be too costly to secure more land, or something of that kind, of course that changes the situation. But if it is possible to avoid it, I think the soil should not be loaded so as to compress it to the point of perceptible settlement.

Mr. Leonard.—In regard to the settling of columns, a device has been used in Chicago, and I am told it is to be applied in New York, consisting of a space left for the hydraulic adjustment at the base of the column, so as to keep the building perfectly adjusted. As it tends to settle, the column is raised and steel wedges are inserted under it. It is taken care of in this way, and at the end of three or four years the building is supposed to have settled to a permanent position and to need no further adjustment.

Mr. Curtis.—On general principles there seems to be something about a foundation which is bound to settle if it is upon the natural soil, and I think we are always likely to have a higher respect for the scriptural man who founded upon a rock than for the man who built his house upon the unconfined sand.

To sum up the discussion, the idea suggested might be that the foundation that would meet all the objections to piles, or to timber and grillage, would be cylinders or wells sunk to the solid substratum and filled with concrete and capped with a concrete base for the whole structure, constructed somewhat upon Mr. Percy's plan, with steel near the bottom and near the top.

Mr. Percy.—I will say, Mr. President, that the nearest approach that I know of to such a method is a church in Paris, the Church of the Sacred Heart. They commenced its construction some years ago. It is a very large, heavy church, and situated on quite a high hill. They found they had a very unsatisfactory foundation. It was a mixture of clay with other materials, and was not at all satisfactory to the engineers, and they sank cylinders down 80 to 90 feet under all the main piers. They went down to the solid stratum and filled those cylinders with concrete, and instead of making a continuous platform under the entire building, heavy arches were sprung from one pier to another. These large cylinders were put down only at points where there would be great bearing. This is the nearest approach to what you suggest, which, I agree with you, would be the perfect foundation, answering all requirements that have yet been suggested.

LOCOMOTIVE COUNTERBALANCING.

By G. R. Henderson, Member of the Association of Engineers of Virginia.

[Read before the Association, June 27, 1896.*]

The subject of locomotive counterbalancing has recently been quite a favorite one, and there have been many valuable papers on this theme, but most, if not all of them, have been deficient in one particular; in that they have not clearly and simply indicated how to proceed with each part of the problem. For instance, one paper gave very carefully worked out formulæ for determining the effect of reciprocating weights, and how to correctly balance them, but the *proportion of reciprocating weights to balance* was passed by with a mere reference, as though of small consequence, when in reality it should be the fundamental question. In the following it is not the writer's intention to advance new theorems, but to select such points from previous papers (including those by Messrs. Parke and Sanderson before the New York and the Southern and Southwestern Railroad Clubs respectively) as, with a few logical suggestions, will place the subject in the hands of every Master Mechanic.

In developing these rules, three cardinal points have been borne in mind:

(1) The amount of reciprocating weight that can be left unbalanced may be a definite function of the total weight of the engine.

(2) The total pressure of wheel upon the rail must not exceed a certain definite amount depending upon the construction of bridges, weight of rail, etc.

(3) The vertical influence of the excess balance must never be sufficient to lift the wheel from the rail.

The first proposition is based on the assumption that the greater the mass, the greater may be the disturbing force without seriously affecting it, on account of its greater inertia.

The second is evidently a rational deduction, not needing any demonstration.

The third is necessary in order to avoid the wheels' jumping off the rail, thereby causing a real "hammer blow."

Starting with the above assumption, we arrive at the following conclusions:

A. Each wheel should be balanced for all revolving weights attached to it.

* Manuscript received July 20, 1896.—*Secretary, Ass'n of Eng. Socs.*

B. The connecting rod is to be considered as part revolving and part reciprocating weight; the proportion of weight of rod which is to be considered as revolving weight varies with the length of the rod as given below:

Length of rod in feet,	5	6	7 & 8	9 & 10	11 & 12
Proportion as revolving weight,	.57	.55	.53	.52	.51

C. The part of weight of connecting rod considered as revolving weight, should be entirely balanced in the main wheel.

D. The amount of reciprocating weight that can remain unbalanced without seriously affecting the locomotive may be found by the formula:

$$Wr = \frac{Wt}{360}$$

Wr = unbalanced reciprocating weight on one side (including portion of main rod).

Wt = weight of locomotive in working order.

E. The remainder of the reciprocating weights should be counterbalanced by dividing the amount equally between the driving wheels on the side, *provided* that the sum of the static weight on any one wheel, plus the centrifugal force of this overbalance, does not exceed the maximum pressure allowed for the particular type of engine in question at the maximum speed at which it will run. If some wheel loads are heavier than others, the lighter wheels may take a part of the overbalance which the heavier wheels cannot without exceeding the specified limit; nor must the centrifugal force exceed 75 per cent. of the static load on wheel.

F. The center of gravity of counterbalance must be opposite the crank.

G. The counterbalance should be brought out from the face of the wheel as far as clearance for the rods and proper design will permit.

H. The center of gravity of counterbalance should be placed as near the rim as possible, and the weight of the counterbalance reduced by this method.

I. Make reciprocating parts as light as possible.

Section *A* is self-evident. *B* is taken from one of the papers above referred to. *C* comes under the same ruling as Section *A*. In *D* the value $Wr = \frac{Wt}{360}$ is taken as representing good practice of the present day. It may be found that some different divisor will be more generally acceptable, but it is believed that the above will give good results.

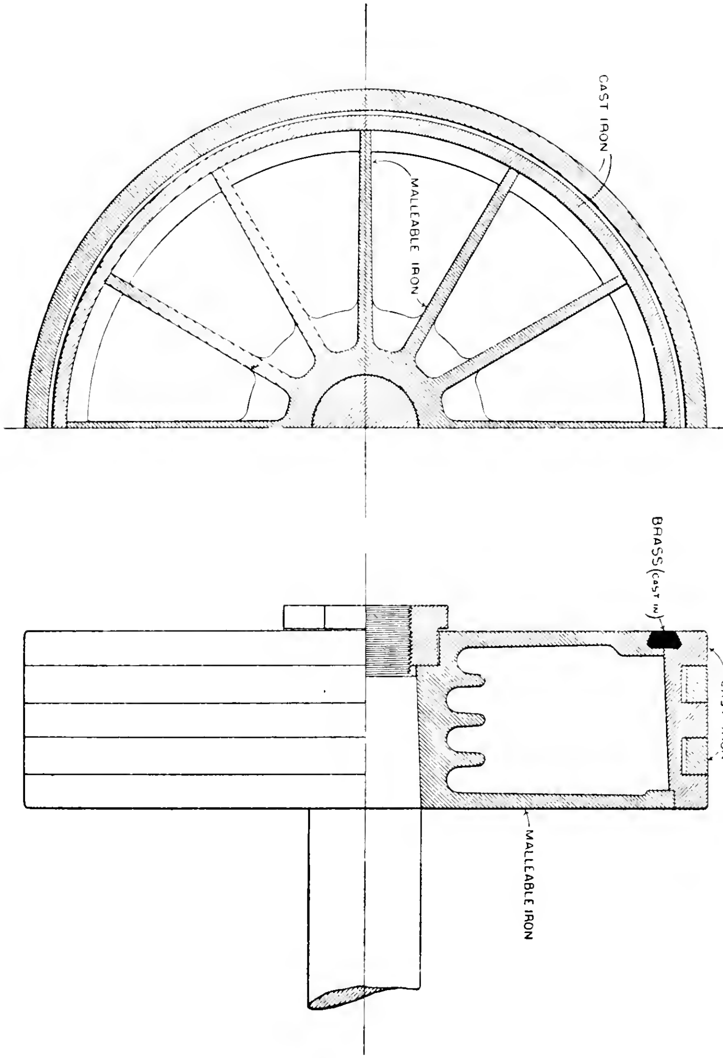

CAST IRON
MALLEABLE IRON
BRASS (CAST IN)
CAST IRON
MALLEABLE IRON

Fig. 1

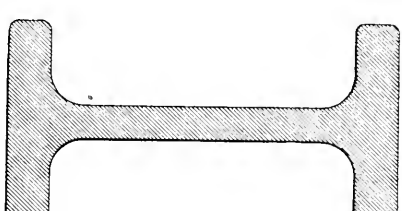


Fig. 2

To determine the centrifugal force for Section E, the following formula is obtained from Weisbach's "Mechanics of Engineering," Vol. I, page 609:

$$P = .00034\ u^2\ Gr.$$

where

P = Centrifugal force.
u = Revolutions per minute.
G = Weight in pounds.
r = Radius in feet.

Now letting

S = Speed in miles per hour.
D = Diameter of wheel in inches.

we have

$$u = \frac{S \times 5280 \times 12}{3.1416 \times D \times 60} = \frac{S \times 1056}{3.1416 \times D} = 336 \frac{S}{D}$$

and

$$u^2 = 112896 \frac{S^2}{D^2}$$

and substituting,

$$P = 38.4 \frac{S^2}{D^2} Gr.$$

As in most locomotives $R = 1$, then we may put simply,

$$P = 38.4 \frac{S^2}{D^2} G.$$

If now we assume that the maximum speed in miles per hour of the locomotive equals the diameter of driving wheel in inches, then,

$$\frac{S^2}{D^2} = 1 \text{ and } P = 38.4\ G, \text{ or say}$$

$$P = 40\ G.$$

It is also necessary to observe the limits of rail pressure. This will be different on various railroads, but on the Norfolk & Western it was taken as follows:

American type of locomotives . .		28,000 pounds per wheel.		
Ten-wheel	" "	26,000	"	"
Consolidation	" "	25,000	"	"

[These loads are per wheel and not per axle or pair of wheels.]

Referring to Section F, it is found that the displacement of the counterbalance necessary to correct the effect of the weights and balance not being in the same vertical plane is so small on outside cylinder engines, that it is accurate enough to place the balance directly opposite the crank. By bringing the counterbalance out as suggested in G, it is possible to still more lessen the irregularity explained just above.

Sections H and I need no explanation.

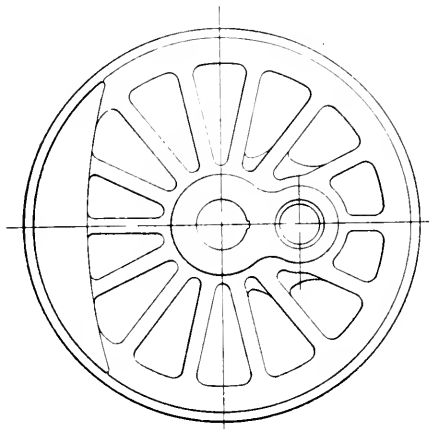


Fig 3

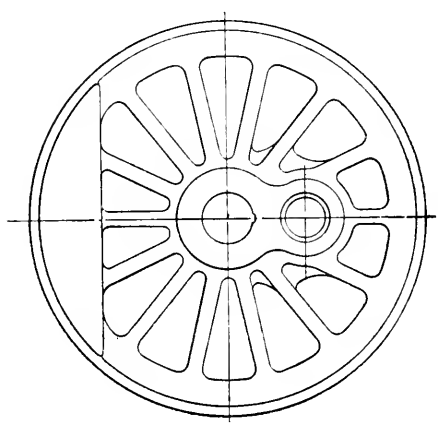


Fig 4

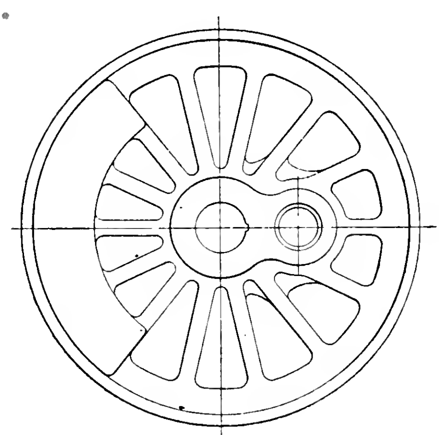


Fig 5

Having taken up these various points, the method of counterbalancing locomotives can now be reduced to the following:

RULE.

Divide total weight of engine by 360, this to be subtracted from reciprocating weights (including proportion of main rod) of one side of engine, and the remainder to be distributed among the driving wheels on one side.

The sum of forty times the amount of reciprocating weight allotted to any one wheel and the static load on the wheel, must not exceed the specified allowance for rail pressure, nor must forty times the amount of reciprocating weight balanced, exceed 75 per cent. of the static weight.

The weights to be put in each wheel will be inversely as the distance of center of gravity of counterbalance from center of wheel is to the crank radius, and must cover all revolving weights as well as the proper proportion of reciprocating weight.

In order to obtain the best results both for the engine and track, the following points should be remembered:

1. Keep the spread of cylinders as small as possible.
2. Make pistons of malleable iron, wrought iron or steel, to reduce weight.
3. Make piston rods of steel, and hollow.
4. Make crossheads of cast steel, of light ribbed construction.
5. Make the rods of steel and of an I section.
6. Keep counterbalances near the rim of wheel.
7. Keep counterbalance as far out as possible.

No. 1 can only be done when designing the engine.

No. 2 can be accomplished in various ways; however, the single-plate pistons have the objection that they freely transmit the heat of steam side to exhaust side of the piston, but double-plate pistons are not readily examined, as they should be, especially when very thin. Besides, a cast-iron wearing surface is desirable, while bolts and rivets are equally undesirable. A design of piston that promises very favorable results, and will meet all the above objections, is shown in Fig. 1. The center is malleable iron, and the wearing ring cast iron, the latter fitting against a shoulder at one side, while a brass retaining ring is cast in and opened out on the other side, making practically a single piece. It also takes ordinary cylinder heads.

For No. 3, the use of nickel-steel has been suggested.

No. 4 depends entirely on the arrangement of guides, etc.

For No. 5. Fig. 2 shows the favorite form.

No. 6 may be accomplished as shown in Figs. 3 and 4, in preference to Fig. 5.

No. 7 is limited by the clearance necessary for the rods, etc.

RIVETED JOINTS.

BY JOSEPH R. WORCESTER, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Society, April 15, 1896.*]

IN spite of the fact that the tendency of the present time is more and more towards the use of riveted work in the construction of bridges and buildings, it is somewhat surprising that we hear of no change towards improvement in the customary methods of calculating the strength of riveted joints. Perhaps it will not be accepted without proof that the tendency of the times is in the direction just noted, but a little careful consideration will show this to be the fact, at least in this country.

The earliest iron bridges in general use hereabouts were constructed with stiff compression members made up of all sorts of rolled sections, or of cast-iron columns, tied together by means of forged rods, which, later on, were superseded by eyebars, and connected by means of pins. Likewise, until quite recently, the only iron used for framing buildings was in the shape of cast-iron columns upon which the beams were supported, the only connections being made by means of straps and bolts. As the science of bridge building developed, and the demands of railroads became more pressing, the speed of trains became greater and the loads heavier, it was found that the light pin-connected structures were gradually being rattled to pieces, the vibrations increasing to an alarming extent. In the endeavor to find some form of construction which would not show these defects, it was natural that we should turn our eyes towards the practice of European engineers and see what advantages we could gain by adopting more of the riveted form of construction, of which many fine examples were in use on the other side of the Atlantic.

It was at this period that a distinguished member of this Society, the late Edward S. Philbrick, designed the many plate girder bridges which have so well served their use in this vicinity for a generation, and which have never proved unequal to their original requirements until their metal was nearly eaten away by corrosion. One, if not more, of these stood until holes were rusted entirely through the web.

About this time some of our bridge companies began constructing riveted lattice bridges. These bridges were a distinct advance upon the earlier forms of pin-connected structures. Their trusses never became

* Manuscript received July 22, 1896.—*Secretary, Ass'n of Eng. Socs.*

shaky in spite of the unscientific connections, the frightfully bad intersections of web members, and the faulty and incomplete systems of bracing; but whenever they have given out, it has been on account of the fact that the floor beams and stringers were not of sufficient strength to carry the increased loads, or the connections in the floor system were not as efficient as the trusses. Many examples of these bridges are doing good service to-day, though probably most of them have had their floor system strengthened or wholly renewed.

Within a short time one of our members has told us that comparing two bridges, a pin and a riveted, of equal theoretical strength, the riveted bridge was very much the stiffer, and consequently, in his opinion, the better bridge.

As time went on, and experience accumulated, we find railroads specifying that riveted girders and lattice trusses shall be required for longer and longer spans, until now we see riveted joints containing two hundred and fifty rivets, to be driven in the field, used in the center truss of a heavy four-track drawbridge, and we see our railroads using plate girders for highway bridges of one hundred feet span. We see all modern specifications for railroad bridges requiring riveted lateral bracing at the track level; while, upon the other side of the water, we see such a bridge as the Firth of Forth riveted throughout, in spite of the fact that our eyebar practice was well understood and carefully considered in England at the time this structure was built.

In our building construction we see the same tendency. The loose strap and bolt attachments are giving place to riveted connections, and the cast iron columns are being superseded by rolled steel sections which will permit better riveted connections.

The object which we are striving for and gaining by these changes is the *rigidity* which seems to be inherent in riveted work.

Notwithstanding this tendency towards the increased use of riveted work, we are still using the same methods of proportioning riveted joints that have been in common practice for fifteen years, in spite of the fact that this practice involves many manifest absurdities.

The earliest authorities on the use of rivets, with more reason than we are in the habit of accrediting to them, took into account only the shearing value of the rivet, but for a long time now we have been taught to use either the shearing strength or the bearing value of the rivet against the metal opposing it, whenever the latter appears to be less than the former. These two strains are all that are considered in modern practice, though some have even gone so far as to consider the fiber strain caused by the bending moment.

In proper riveted work the writer ventures the assertion that neither one nor the other of these strains is exerted to any extent, and

it is with the intention of proving this assertion that the present paper is presented. It is not denied that before riveted joints will fail both bearing and shear will come into play, but when we are considering *proper* work we mean a class which is not on the point of failure and has not even reached the limit of elasticity, which it does as soon as a joint shows any permanent set. The rigidity, which is the essential characteristic of this form of construction, would not appear if rivets allowed a motion to take place between the thicknesses of metal connected. The force, therefore, which should be considered in designing the riveted joints, is that force which is exerted by the rivets to restrain the parts from all motion and to hold them in the precise position in which they are riveted.

The easiest way to demonstrate that it is neither bearing nor shearing strength which causes the rigidity of riveted work, is theoretically, though we can quote also a number of practical illustrations which help to confirm this position. When a rivet is driven hot it is supposed to fill the hole, which is usually one-sixteenth to one-eighth inch larger in diameter than the rivet. This filling of the hole which specifications always stipulate, is more or less perfectly accomplished. When the holes are fairly concentric in the various thicknesses through which the rivet passes, the punch and die being not far from the same size, and the rivets are driven by a powerful machine, the metal will upset into the hole for a considerable distance until it apparently fills the void spaces ; but when the rivets are driven by hand or when the holes have large tapers, or when the rivet passes through a number of thicknesses, there are sure to be voids of considerable dimensions. Under the most favorable conditions, however, we must remember that at the time the rivet is driven it is at a much higher temperature than the surrounding metal, and as it cools it must inevitably contract, and in so doing draw away from the surface of the hole against which it was pressed. A section cut through a riveted joint in the axis of the rivet will show in a superficial examination the rivet to be in close contact with the surrounding metal, but with a magnifying-glass, or with the point of a needle, it is very easy to see that the contact between the rivet and the surrounding metal is not as close as that between the head of the rivet and the surface of the plate, or between the various thicknesses of plate tied together.

It is this fact of there being a little play around the rivets which prevents their acting either by bearing or shear until there has been a little slip between the plates, that is, until the joint has passed its limit of elasticity. Up to the point when the slip occurs the force which prevents motion must be the friction caused by the pinching together of the surfaces by the rivet heads. That this frictional resistance must

be the force upon which we depend for the rigidity of our riveted structures may be practically shown in various ways. In the first place a great many experiments have been made on testing machines which invariably show that as the strain is applied the joint in the first place stretches only just as much as the metal itself stretches and in direct proportion to the amount of the strain. During this period, if the tension is relaxed the specimen returns to its unstrained position, but as soon as the friction is overcome a certain motion occurs, the

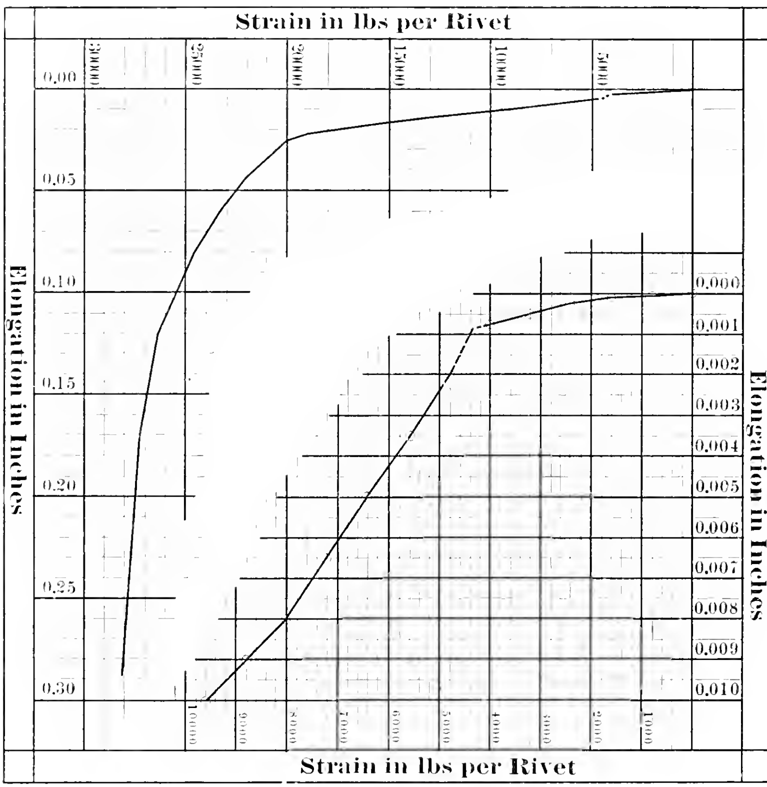


Diagram Showing Slip of Rivets.

extent of which depends upon the void spaces around the rivet. After this the specimen shows a permanent set and the joint will go on stretching in an irregular fashion, as the metal around the rivet comes into full bearing. The diagram herewith presented illustrates this slipping very forcibly. It is taken from a series of experiments tried at the Watertown Arsenal in 1886, and is a fair sample of the several hundred tests made at that time.

In this diagram, the curve on the left shows the total elongation of the joint until nearly the time when failure takes place, the ordinates indicating the amount of strain per rivet, and the abscissæ showing the stretch of the joint. The curve on the right shows the early part of the same curve on a magnified scale, the points at which the elongation is recorded being indicated by circles.

As will be observed, up to a strain of about 4,000 pounds per rivet, the elongation is approximately proportioned to the strain, but at about 4,300 pounds a sudden slip occurs. The exact point of slip is not recorded, the curve at that point being indicated by broken lines, which are produced by extending the general direction of the lines above and below the nearest observations.

Another method of showing practically that rivets do really hold by means of friction is by considering what would occur in the case of a plate girder with a large number of flange plates. In such a place as this it is impossible for any ordinary riveting machine to more than partially fill the holes. Any one who has had experience in cutting out very long rivets must have noted that they are easier to back out than short rivets through two or three thicknesses. The reason is that when the pressure of the riveter is applied to the end of the rivet it begins to upset at the extreme point, and as it upsets it fills first the part of the hole nearest the driving-head. As this fills out into the irregularities of the whole, it jams, so that it is impossible to force enough metal in through the hole to fill out the voids near the head end. We have, therefore, in this case even more play around the rivets than would occur where the hot rivet was completely upset. But these rivets have to transfer the strain from the flange angles to the outside plate, often a distance of several inches. If we imagine such a plate girder put together with loose-fitting pins, which indeed it would be were it not for the friction, it is evident that the girder would have to get a very considerable set, and the web and angles perhaps fail before the whole flange would come into play, if it could at all.

Another example of about the same action is where we see connections made through loose fillers. We can often find in good practice the end-uprights of a stringer which transfer the whole shear from the stringer web to the supporting floor beam, packed out to the thickness of the flange angle by means of a bar of the same width as the upright. In this case if there were not friction exerted it is evident that the rivets would bend quite appreciably and thus allow the stringer to drop before bearing and shear came into play. Another evidence of the fact that it is the friction which is effective may be found in numerous examples of girders which were formerly constructed with very thin webs, and which with a bearing strain of the rivet against the web up to and

above the elastic limit of the material, have not shown the least sign of motion. The writer has in mind the case of a bridge on the Old Colony Railroad which was removed a few years ago, where this bearing strain caused by the every-day traffic of the railroad, amounted to 20,000 to 30,000 pounds per square inch, without allowing anything for the effect of impact.

That this fact of frictional resistance has been really recognized by engineers can be evidenced by the sensible though not very common practice of allowing a greater strain in bearing on metal enclosed by thicknesses acting in the opposite direction, than where not so enclosed. This practice appears to have originated in the thought that in a case of single shear the rivet would naturally bear upon the edge of the hole nearest the plane of shear with greater force than upon the other side of the plate, but the effect of the specification is in the line of taking account of the friction, of which we naturally have twice as much in the case of enclosed bearing as in that of not enclosed, and this fact is often advanced as an excuse for the practice.

The most conclusive experiments on the question of friction in riveted joints that the writer is aware of, were made in France two years ago, by M. Dupuy, Inspector-General of Bridges and Highways, who was intrusted by the Ministry of Public Works with the duty of making special inquiry into the causes of deterioration of metallic structures. A full account of his experiments and conclusions was presented in *Les Annales des Ponts et Chaussées*, January, 1895.

The experiments were conducted with the greatest care, especially to determine the strength of the rivet before reaching the limit of elasticity. The conclusions which he reached are based upon a very clear and convincing argument drawn from the experiments. The following points which he arrived at seem to be unassailable:

1. Rivets are stretched bars undergoing a tensile strain higher than their initial limit of elasticity. The fibers of the circumference appear to be more stretched than those of the center.

2. Rivets do not quite fill the holes, but exercise a very strong clamping effect which causes between the plates a resistance to slipping equivalent to a welding.

3. The resistance to slipping of riveted plates increases as the limit of elasticity of the metal of which the rivets are composed increases.

4. The limit of resistance to slipping is extremely variable. The causes of this variation appearing very numerous and depending (*a*) upon the nature of the metal of which the rivets are composed, and (*b*) upon the temperature at which the rivets are driven ; (*c*) upon the temperature at the completion of the operation of driving ; (*d*) the method of riveting ; (*e*) the manner in which the operation is conducted.

5. The resistances to slipping upon which we can count in practice in connections composed of three rivets or more, in pounds per square inch of rivet section to be sheared, are shown by the following table:

	Steel Rivets.		Iron Rivets.	
Original Limit of Elasticity in pounds per square inch.	29,900	32,700	25,600	29,900
Hand-Driven Rivets heated to a bright red heat, the dies leaving no mark on the plates, the operation being finished when the driven head has become black.	6,400	7,110	5,690	6,680
Power Rivets heated to a white heat, driven with a pressure equal to 85,000 pounds per square inch of rivet section, the pressure being maintained until the head has become black.	8,530	9,390	7,110	8,250

The limits of elasticity mentioned above are those which are found in testing specimens previously heated to a dull red.

The metals employed in making rivets should have an elongation of at least 12 per cent. for iron and 18 per cent. for steel.

6. If a riveted joint is subjected to a strain sufficient to cause the thicknesses to slide, even if the motion is enough to distort the rivets, the distortion will remain after the strain is removed, but it appears that no further distortion can be produced without a greater strain than that which caused the original distortion.

After establishing his conclusions in regard to riveting, M. Dupuy goes on to deduce rules for designing bridges, which, for the most part, are admirable, especially those relating to the desirability of avoiding secondary strains as far as possible by making perfect intersections of diagonals with chords, etc., but he draws some conclusions which seem to run counter to the ideas which have been gaining ground in American practice, and which require further demonstration before we can accept them. For instance, he recommends that panels shall not be made longer than 11′ 6″ to 13′ 0″. He also recommends that in double Warren systems of trussing, verticals shall be used at each panel point to connect the two systems and so equalize the strains. He further advises that bridges of several spans shall be made continuous over the piers where there is no danger of a settlement, though he would not ad-

vise the continuity to extend over so great a number of spans as to induce large strains on account of temperature changes.

The writer has attempted, by careful examination of the reports of tests at the Watertown Arsenal, to verify the experiments of M. Dupuy, but the examination has not proved altogether satisfactory, for the reason that the reports do not indicate precisely the point at which the first slip takes place. The stretch of the specimen is indicated at certain intervals, and it is easy to see that at some point the slipping takes place, but the points of observation are not sufficiently close together to indicate the exact point where the motion begins to occur.

Another reason why the experiments are not wholly satisfactory is that the bulk of the experiments have been tried upon a single row of rivets driven as in boiler shells, the rivets in most cases being much closer together than three diameters center to center, under which circumstances the frictional action does not seem to work to so great an advantage.

The following tables give the average of a large number of tests, the strain indicated being the shear per rivet at the last observation point before the slip occurs :

TABLE I.

Earlier Tests of Rivets in Single Shear.

Force required to produce a slip in pounds.

Diameter of Rivet.		Thickness of Metal.			
		$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$
Iron Rivets . . .	$\frac{7}{16}$	1775			
	$\frac{5}{8}$	3810			
	$\frac{11}{16}$		3904		
	$\frac{3}{4}$			5200	
	$\frac{15}{16}$			7000	
	1				8625
Steel Rivets . . .	$\frac{7}{16}$	3750			
	$\frac{5}{8}$	4000			
	$\frac{11}{16}$		4333		
	$\frac{3}{4}$		5000		

TABLE II.

LATER TESTS OF IRON RIVETS IN DOUBLE SHEAR.

Force required to cause a slip in pounds.

Diameter of Rivet.	Thickness of Metal.				
	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$
$\frac{9}{16}$	4012	4150			
$\frac{11}{16}$	4000	5012	4525		
$\frac{13}{16}$	3833	5250	6130	6300	
$\frac{15}{16}$	4400	4740	5400	7200	6700

It appears from these tests that, while the thickness of the metal against which the rivet bears plays little part in the frictional strength of the joint, it seems as if it is necessary to get a tolerable length of rivet before the clamping effect can be fully developed, for we see in no case an increase of strength at all proportional to the thickness. We even find for the thickest plates less strength in some cases than with thinner metal. It does, however, appear that with the thinnest metal, that is, where the rivet is very short, we fail to get quite so high results as with a little longer rivets.

The explanation of the fact that, in these tests, the larger diameters of rivet do not seem to be as efficacious as the smaller, may be partly due to the fact that the pitch of rivets is more suitable for the small than the large sizes, and they should not be considered as discrediting M. Dupuy's results on account of this disagreement, but it is exceedingly desirable that further experiments may be tried, to enable us to determine whether he is correct in assuming that the frictional strength is proportional to the area of the rivet section.

It is interesting to note that the behavior of the specimens under test was exactly the same as the French experiments showed. This is clearly described in the following extract from the report of Mr. J. E. Howard, C. E., which accompanies the tests quoted above:

"The progress of the test of a joint is generally marked by three well-defined periods. In the first period greatest rigidity is found, and it is thought that the joint is now held entirely by the friction of the rivet heads, and the movement of the joint is principally that due to the elasticity of the metal.

"The second period is distinguished by a rapid increase of stretch of the joint, attributed to the overcoming of the friction under the rivet heads and closing up any clearance about the rivets, bringing them into

bearing condition against the fronts of the rivet holes. Rivets, which are said to fill the holes, can hardly do so completely, on account of the contraction of the metal of the rivet from a higher temperature than that of the plate, after the rivet is driven.

"After a brief interval, the movement of the joint is retarded, and the third period is reached. The stretch of the joint is now believed to be due to the distortion of the rivet holes and the rivets themselves.

"The movement begins slowly, and so continues till the elastic limit of the metal about the rivet holes is passed, and general flow takes place over the entire cross-section, and rupture is reached."

If we, then, assume that the experiments, both here and in France, are sufficient to establish the fact that the first action of the rivets is to hold by friction, the question arises, whether it is not possible to adopt specifications based upon this force, which will give more perfect results than those attained by using bearing and shear.

A few of the objections are:

1. Want of tightness of the rivet. Of course, if the rivet is not tight it does not hold by friction, but this is no argument against using friction in proportioning the joints, because a loose rivet is bad anyway, and one such in an otherwise perfect joint cannot be said to do any good, whether the rivets are figured by bearing or shear.

2. The rivet may be driven through thicknesses which are not in perfect contact, and from the stiffness of the plate may appear to be tight when it is not really exerting as much pressure as the metal is capable of. This defect, while it certainly may be a serious one, especially when hand-driven, could not exist if the thicknesses were properly clamped together during the process of driving, and it can only be said that it is as much a source of weakness, no matter how the joint was originally proportioned.

3. Another objection which occurs to the writer, is the doubt whether a joint may be lubricated by oil or paint applied to the contact-surface to such an extent as to appreciably alter the coefficient of friction. As to this point, it is exceedingly desirable that more experiments may be tried, and possibly some of the members present can supply information on the point which the writer has not succeeded in finding. Without mentioning the fact that it is of very doubtful utility to apply paint or oil to surfaces which are to be riveted in close contact, it is the firm conviction of the writer that the heat of the rivet and the squeezing effect produced by the process of riveting entirely dissipate any effects from this cause.

Among the many advantages may be mentioned the following:

1. Simplicity. Evidently it would be much simpler if we could neglect the thickness of plates and consider only one value for a single shear of a certain-sized rivet.

2. Comparative accuracy. While we may not be able to determine exactly the frictional strength of a rivet as long as it actually holds by friction, it does not seem as if we could gain much by considering two other functions, such as bearing and shear, which do not really act at all.

3. The doubtful and uncertain questions arising in case of indirect transmission would be entirely avoided.

4. When we realize that rivets hold by friction we free our minds at once from two complications which are apt to be troublesome in designing, viz., the questions of fatigue and reversal of strains, for neither of these has any effect upon a joint holding by friction.

5. A true conception of how rivets hold would prevent some details of construction which are now quite frequent. It is often convenient to drive two knees (between which a gusset or a beam web is to be inserted later) to some supporting members, the knees being purposely left a little wide apart to allow easy assembling. It is sometimes found convenient to drive the flange rivets of a girder before the web rivets, and the writer has even known of the flange angles of a large girder being shop-riveted to the flange plates and shipped separate from the web plates, which were afterward inserted and hand-riveted. Such practices which destroy all possible frictional action, could not be tolerated if we counted on this force.

6. It may be well to note that in adopting this method of figuring we are running no risks, because in the few cases in which this method would allow a larger strain on the rivet than the old method, even though the friction should give out and the rivet should slip so that the bearing would come into play, we have abundant evidence that no disaster can result worse than a slight set in the joint.

As to the safe values to allow for the frictional resistance, it may simplify the consideration to think of the force as depending upon the clamping power of the rivet multiplied by the coefficient of friction.

The clamping effect is produced by the contraction of the rivet in cooling. If the pressure of the machine, or of the bolts in the case of hand-riveting, is sufficient to bring the thicknesses riveted into close contact and the rivet is properly heated, the contraction is greater than the possible elongation of the metal of the rivet within the elastic limit. The result is that the strain in the rivet is just enough to stretch it. M. Dupuy verified this fact by some very ingenious experiments, which are fully described in his paper above quoted. This being the case, we have one of the elements upon which the friction depends, determined with considerable precision. The other element, the coefficient, must necessarily be determined experimentally. Judging by experiments of Rennie, it would be in the neighborhood of $\frac{4}{10}$ and considering the fact

that the pressure is very great, and that there is always a certain amount of unevenness around a hole which would tend to increase the coefficient, it seems as if we could count on about this figure with reasonable certainty. This is confirmed by the result of Watertown tests of rivets driven in slotted holes. In this case it was found that $\frac{5}{8}$ rivets in single shear required a force of about 5,000 pounds to produce a slip. This is equivalent to a strain of 15,340 pounds per square inch, or probably a coefficient of friction of $\frac{6}{10}$. The elastic limit multiplied by $\frac{4}{10}$ would give for steel about 12,000 pounds per square inch of rivet section, and for iron about 10,000 pounds, but these values are above the usual allow-

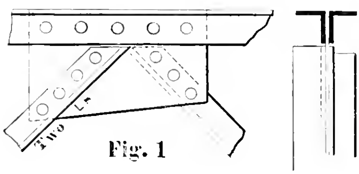


Fig. 1

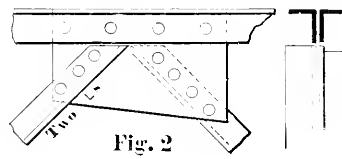


Fig. 2

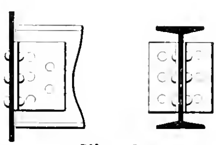


Fig. 3

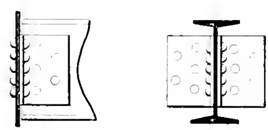


Fig. 4

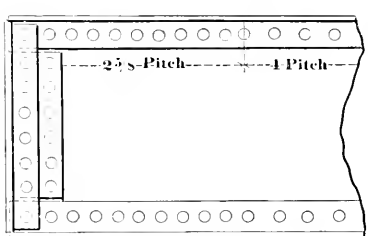


Fig. 5

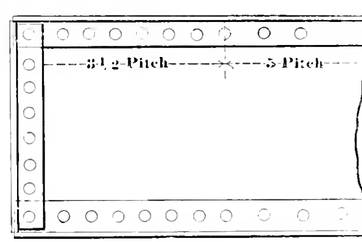


Fig. 6

SKETCHES OF DETAILS DESIGNED WITH AND WITHOUT REGARD TO FRICTION.

ances for shear. It seems, therefore, to the writer, that if we should only figure out rivets for shear, recognizing all the while that it is the friction which is holding and assigning safe shearing units, we should be approaching much nearer a truly economical and consistent design than by considering bearing.

This may be a step backward, but it is possible that in departing from the rules of our predecessors we have not gained as much as we think.

While it is not the object of this paper to go into the question of

a proper specification, it may be well to state that considering the question of friction, there ought to be more distinction made than is usually done between allowable shear on hand-driven and machine-driven rivets.

A few sketches are herewith presented showing ordinary bridge connections as they would appear designed in the common way and also by means of frictional resistance.

The sketches on the left, Figs. 1, 3 and 5, represent ordinary joints calculated for bearing and shear as in ordinary specifications. Those on the right, Figs. 2, 4 and 6, show the same joints calculated upon the basis of frictional resistance.

As will be noticed, the number of rivets required is sometimes more and sometimes less, when the friction is taken into account. While on the average the number of rivets used may be about the same, it is thought that the distribution can be improved and more strength gained by considering the friction.

DISCUSSION.

By Edward S. Shaw.—The subject of the increase of strength of riveted joints under ordinary working strains, due to the friction of the contact-surfaces of the plates or shapes riveted together, and the question of how much of the strength of the joint is due to this friction, are interesting matters, which doubtless have not heretofore had the consideration that they deserve from engineering writers and experimenters.

The existence of this frictional resistance has long been known, but the older authors of engineering text-books, so far as the knowledge and memory of the writer goes, dismissed the subject in much the same way as Trautwine, who says: "The friction between the plates in a lap, or between the plates and the covers in a butt, produced by their being pressed tightly together by the contraction of the rivets in cooling, adds much to the strength of a joint while new, perhaps as much as 1.5 to 3 tons per square inch of circular section of all the rivets in a lap, or of all on one side of a single-cover butt; or 3 to 6 tons of all on one side of a double-cover butt. In quiet structures, this friction might continue to exist, either wholly or in part, for an indefinite period; but in bridges, etc., subject to violent and incessant jarring and tremor, it is probably soon diminished or entirely dissipated. Hence good authorities recommend not to rely on it, and it is therefore omitted in what follows."

If we admit the universal existence of this friction as a factor, even

if not the controlling one, in determining the number and strength of the rivets, it would seem also to have an appreciable effect upon the net strength of the plates connected by splices in a riveted bridge joint, for beyond the last rivet or last line of rivets in the joint, the splice plates extend, pressed to the main plates with a certain strength of grip which must be overcome before the plate can tear on the outer rivet holes.

Mr. Worcester should have the thanks of all engineers interested in bridge designing and construction, for the careful and able manner in which he has collected the somewhat meager data existing upon this subject and drawn general conclusions therefrom.

It is to be hoped that he will continue his investigations so far as to present a complete and rational method, at least for the spacing of rivets in the webs and flanges of plate girder bridges.

In regard to the general application of this method, there would seem to be more than a few difficulties, especially in connection with field-riveting.

We have learned to regard the proper upsetting of the rivet, and filling the hole as well as possible, as of utmost importance. It is, however, too much to expect of the average field-riveting gang, that they will get perfect heads on all their rivets, and make them tight and well upset in the holes at the same time; and it has been the practice of the writer to accept a limited number of unsatisfactory rivet heads, especially in difficult positions for driving, provided that the rivets were otherwise well driven.

The substitution of the author's method would require a reversal of this rule, for if the plates are to be held together by the grip of the rivet heads, it is essential that there should be no small, flat or thin-edged or badly eccentric rivet heads, for though at first the grip may be sufficient with a flat head or small bearing surface, yet rust and other causes are very liable to diminish or destroy this surface and grip.

The writer must express views in opposition to the fourth conclusion of the author, viz.: "When we realize that rivets hold by friction, we free our minds at once from two complications which are apt to be troublesome in designing, viz.: the question of fatigue and reversal of strains, for neither of these has any effect upon a joint holding by friction."

In contradiction to this may be placed the old theory, well expressed by the statement of Trautwine quoted above in regard to the effects of impact and vibration ("jarring and tremor"), the same causes, or results of the same causes, which are supposed to produce fatigue in the main members and which are operative in necessitating a diminution of the allowable strains, with increase of live load or reversal of strain. The rivets being in a high state of tension, (according to the French experimenter quoted by the author, beyond the primary elastic

limit of the rivet material) it would seem to the writer that they must be especially sensitive to the fatiguing effects of dynamic influences acting upon them through the media of the plates or parts connected, while the action upon the rivets caused by the movements of extension or compression of the members connected, however slight, will apparently, in time, tend to diminish their grip and the resulting friction, in about the same ratio that the microscopic molecular changes of deterioration or fatigue in the main members are produced.

Therefore, if it is proper to vary the unit strains in the principal members with variations in the ratio of minimum to maximum, then it would seem to be equally proper and thoroughly consistent to vary them in a proportional or similar manner in the rivets.

By John C. Moses.—The so-called "factor of safety" has frequently been termed a "factor of ignorance," and the writer of the paper has clearly shown the truthfulness of the charge in the case under discussion. But no engineer can really be satisfied with factors of ignorance, and so we find him constantly trying to eliminate the guess work and substitute what is known to be correct. The most satisfactory method is to make experiments and reason from them as a basis. It is positively appalling to think of the amount of mental labor involved in arriving at our present theories of the action of structures—mental labor that a few actual experiments would so greatly assist. These experiments are not made because, on the one hand, no manufacturer is sufficiently disinterested to do a work that will not bring him a direct gain unshared by others; and, on the other hand, no purchaser feels called upon to pay for experiments that will benefit everybody as well as himself. No one questions the need, but they say it benefits everyone, and so everyone should help pay for it. Consequently it is not done. The writer speaks of the possible effects of paint as a lubricant of riveted joints—he *thinks* its effect is inappreciable, but perhaps ten years from now someone will spend five hundred dollars and find out. We have waited many years for the experiments on riveted joints in tension cited in the paper. The French experiments were made possible by government aid, but we cannot expect that in this country.

A recent article in the *Engineering News* demonstrated that the standard beam connections in common use are only worth from one-fourth to one-half the commonly assumed values "if the effect of friction be neglected." We all know this, but we also know that rivets have a value aside from their shearing and bearing values, and we *guess* that it is enough to counteract the effects of eccentricity. This is a very crude approximation. A hundred beams connected as in actual practice, and loaded until the elastic limits of the joints were reached, would give us a new basis for our theories, and probably enable us to save a pound or two

of metal in a joint, while at the same time making it a stronger piece of work. To accomplish a better result with less money is to be an engineer in the truest sense. How long would it take to pay for the experiments if an average of one pound a joint could be saved as the result? Meantime the profession is daily making a ridiculous assumption, because no one makes the experiments. What better work could be found for an engineering society to do? Manufacturers can be interested if some one will take the initiative. Testing machines and men to run them can be found in Cambridge and Boston, and the cost of the materials need not be great. Our last president has suggested dividing our Society into groups, each one in turn furnishing the paper of an evening. The report of the Committee on Standard Connections for Beams would make an interesting subject for some of us, and if properly done it would be a distinct addition to engineering knowledge and a new demonstration of the usefulness of this Society. There are, of course, many other questions awaiting similar solutions; this one is merely suggested as an example, the solution of which is indicated in the evening's paper. One cannot help thinking, as he reads that paper, how much more satisfactory it would be if the author had been able to base it on more extensive experimental data. If he could have positively told us that it was correct to use the shearing values of rivets when spacing them in flanges of girders, the information would save several per cent. of the cost of the work done in the establishment with which the writer is connected. As it is we will feel safe to use a somewhat higher bearing value for rivets than has been our custom heretofore.

By James E. Howard. — That riveted plates are held together by a very substantial gripping pressure exerted by the rivets in cooling, there can be little doubt. A consideration of the coefficient of expansion by heat shows that rivets need cool only over a limited range of temperature in order to be strained to their elastic limit. This zone of temperature is of such limited range that the known changes in the modulus of elasticity and elastic limit under higher temperatures has but slight influence in the results, and it is believed that under favorable conditions rivets in their final state may be left gripping the plates of a joint with a force nearly or quite coincident with their elastic limits.

In hydraulic riveting the conditions seem favorable for reaching good results. Rivets in their upset state may, however, have a lower elastic limit in consequence of the upsetting than possessed by the metal in a rolled bar.

That rivets are strained nearly to their elastic limit the tests of the joints seem to afford some proof.

In the early stages of a test it is frequently observed that the scale starts off the rivet heads, and when this occurs under a comparatively

low stress on the joint it is taken to signify that the rivets were nearly ready to scale when the joint was at rest.

A critical comparison of the strains developed in a joint and those which should be developed in the solid plate, adopting a modulus of elasticity of 30,000,000 pounds per square inch, shows that joints very frequently elongate more than a solid plate should elongate, and that permanent sets appear early in the joint.

So far as these minute changes in shape are at present explainable it would appear that while in the main frictional resistance prevents general slipping of the plates, yet slight distortions are permitted to occur.

It is difficult to ascribe an adequate cause for this behavior. Perhaps it signifies the release of internal strains, where conflicting strains existed due to the contraction of the parts while cooling after riveting.

Possibly the most advantageous case for maximum frictional resistance is found in a joint containing a single row of rivets, running at right angles to the line of applied stresses.

Where several rows of rivets are used, the outer rows necessarily are obliged to permit some movement of the joint in order to bring the inside rows into action. Just why Mr. Worcester considers experiments made in a single row of rivets unsatisfactory (see page 40) does not appear to be explained, nor why the spacing should exceed three diameters for the frictional resistance to work to advantage. Data seems needed to show what part of the maximum frictional resistance existing or supposed to exist in a joint is available for use in a structure. Perhaps an experimental inquiry into the behavior of joints exposed to alternate and variable stresses and also vibratory influences would aid in answering this question.

By Gaetano Lanza.—(1) The chief objection to Mr. Worcester's theory is, of course, the fact which Mr. Howard has already mentioned, that the stretch due to the application of the load on a riveted joint is always greater than that due to the stretch of the metal, and hence that there is no load which does not cause slipping.

(2) Moreover, if, as I suppose Mr. Worcester must have tried to do, we seek for a load at which the rate of slipping increases very decidedly, we shall find, in many cases, that the increase in the rate of slipping is gradual.

(3) Were the action such as Mr. Worcester describes, it would be a dangerous proceeding to design joints on the basis of the friction alone, without considering their strength, as it would be possible, on that theory, to make a joint having more frictional resistance than strength, or, at least, where the frictional resistance formed a large proportion of the strength and the factor of safety was very small.

(4) The experiments of Dupuy seem to me to be too few in number, and also, for the most part, to have been made on joints with too few rivets to warrant the conclusions drawn. The determinations of stretch were much coarser than those of the tests at Watertown arsenal, and the fourth group of joints were tested on a machine in which piston friction was allowed to vitiate the results.

Of the other three groups, the first was the only one where there were as many as four rivets on each side of the joint, and these were hand-riveted; the number of tests being four. In the second group of seven joints there was only one rivet on each side of the joint, and in the third group of twelve joints there were only two rivets on each side of the joint.

By J. P. Snow.—It seems to me that the web rivets in plate girder flanges get the advantage of frictional resistance more than those in almost any other situation. If the web tends to fail by bearing, that is if it starts to buckle around the rivet hole, the angles held by the flange plates prevent it and this action tends to increase the friction rather than to diminish it, as would be the case in a simple connection where the rivets act in single shear. Oftentimes, when designing under the usual specifications, the thickness of webs is governed by the rivet bearing near the ends. I think that the usual unit strains might be safely exceeded in these cases. So far as I have been able to judge from observing old girders, the thickness of webs is a part that may be allowed to vary more widely from established units than other members of the structure, and it is hardly conceivable that one could be so badly designed as to fail from the insufficiency of flange rivets. It must be the friction that helps in these cases, and I believe that it is legitimate to take advantage of what we know must exist in proportioning new work, although I acknowledge I have never had the courage to raise these units appreciably.

It is troublesome to arrange a general specification so that it will cover extreme cases without running into absurd results; this makes it difficult to provide for all the varying cases where it seems advisable to depend wholly or partly on the friction. The cautionary legend that Mr. Cooper puts at the head of his Standard Specification is well placed; much depends on the judgment of the designer. It is, however, feasible to provide for a different unit for hand-driven and machine-driven rivets and for rivets in single and enclosed bearing. The practice on the Boston and Maine Railroad is to allow 25 per cent. more on machine-driven than on hand-driven rivets and 25 per cent. more on rivets enclosed between two thicknesses than on those acting in single shear.

I heartily agree with the paper in the matter of making these allowances, and in crediting the friction with a generous ratio of its

ultimate value in the case of web rivets in plate girders. In cases of connections where the rivets act in single shear, however, especially when they are hand-driven, it will hardly do to allow more on a rivet than the bearing area or shear could properly carry, because these surely are the ultimate dependence if the rivets from any cause become loose. The examples shown by the author call for more rivets in this class of connections than the usual rule. How this would work out for different thicknesses cannot be told without a definite specification. It is probable that in thin metal less rivets would be called for by the new rule than the old. The usual number should be reduced with caution, for although it may be that rivets do not get loose much worse in thin metal than in thick, yet after a rivet is loose the thin metal goes to destruction much the faster, and it is hardly to be expected that any set of rules will prevent rivets getting loose occasionally. This is off the question somewhat perhaps because the paper considers "proper rivets only" and those which become loose cannot be called proper; but we must deal with actual conditions and try to design work to meet them.

In the structures under consideration we must unfortunately depend on hand-driven rivets and generally on those acting in single shear to perform the most important function of all, that is, to connect the various members together; while the rivets of less importance, that is, those holding together the integral parts of a member, can be machine-driven. This condition operates in several ways to the disadvantage of riveted trusses. Being so vitally important, and at the same time of so low efficiency, we must have plenty of them. They are what hold our structures together and we must not depend too much on so uncertain an element as friction.

As to the superior rigidity of riveted trusses alluded to in the paper, it is probable that the form of section has as much to do with it as the style of connection. The flanged sections in pin trusses vibrate but little, while flat bars in riveted ones are but little more rigid than if connected by pins. I think if satisfactory joints could be arranged in pin-connected trusses when using flanged sections like angles, zees and channels throughout, the resulting structure would be as satisfactory in the matter of rigidity as it would be if riveted.

It is very interesting to compare European practice with ours, as is done by the author. On the whole it seems to me that the Americans have been the most ready to drop what is bad in their past practice, and to adopt the good from foreign design. In our solid-floor bridges, we have certainly improved on the English designs, and in our long-panel trusses we have dropped most of the objectionable features of early American flimsiness. The Europeans seem to cling to their clumsy short panels. Some American designers claim that long panels only are right, that

panels less than 20 feet should be frowned upon. It does not seem to me that the length of panel *per se* affects the efficiency of the bridge at all. This element as well as the style of the bridge should be adjusted to meet the conditions. Within twelve months we have designed bridges for the Boston and Maine Railroad with panels varying from 2 feet to 23 feet, and so far as I know they are equally strong and serviceable. It was surely our endeavor to make them exactly equivalent. Our practice is equally varied in the matter of pin and riveted work. I believe that each has its place. He who will use both and can keep each in its proper field is certainly employing the art of bridge building to the best advantage.

By Joseph R. Worcester.—The interesting questions which have been raised by the discussions of the paper have shed light on a number of points which have not been sufficiently elaborated in the paper itself, and the author is very glad to acknowledge that many of the criticisms are well founded. There have, however, been a few points raised which perhaps can be explained.

With regard to Mr. Shaw's points about field rivets it appears to the author that the danger in this class of work is not so much from imperfect heads as from the fact that the holes are not completely filled. If such be the case, unless we are willing to allow considerable slip when the load is applied, it is essential that we should provide rivets enough to hold by friction. The head must be very bad if it is not sufficiently enlarged to grip the plates together when the rivet cools. In the author's opinion it is better to use bolts where good rivets cannot be driven, for a bolt well drawn up is much better than a loose rivet: one loose rivet in a joint is absolutely useless until the others have yielded.

So far as the action of repeated or reversed strains affect the question of friction, if we have no motion between the surfaces clamped together, we have a constant strain in the rivet. It is not apparent, then, how the rivet can be weakened by any number of variations of stress.

Of course, if there is any motion the strength becomes less with each slip and we soon have a loose joint. It is therefore all the more important to provide rivets enough at the start to prevent motion.

Mr. Howard's careful consideration of the effect of the friction is very instructive, and his explanation of the variation of the elongation during the earlier stages of the tests from that which would occur in solid metal appears quite reasonable. The author's only reason for suggesting that a less spacing than three diameters may not give as good results as a greater is from observation of the large number of Watertown tests made with all kinds of spacing. It certainly seems necessary that more tests should be made to definitely determine this point.

While the author agrees with Prof. Lanza that it is somewhat difficult to determine from the Watertown tests the point where a decided slip takes place, in most cases it is very evident that there is such a point, as may be seen by carefully plotting the extensions. The author cannot agree as to there being any danger in considering the friction in the method suggested in the paper, and it is not easy to see what is meant by a joint having more frictional resistance than strength. It is not, of course, proposed to govern the thickness of the plates or parts connected by the frictional resistance of the joint, as this element is invariably settled by other considerations.

With regard to the experiments of M. Dupuy, while the author does not quote them as being conclusive they seem to be particularly instructive on account of the thoroughness with which the minute elongations were observed under light strains and also on account of the care exercised in determining the physical conditions of the rivets.

The remarks of Mr. Moses with regard to the difficulty of securing an adequate number of tests must be apparent to all. It is very much to be hoped that in the future this subject will not be so neglected as it has been in the past.

The author is pleased to note the extent to which Mr. Snow has been willing to consider friction in his own practice.

In conclusion the author cannot but repeat what he has stated in the paper that while in good practice, that is, in work that is not strained above one-half its elastic limit, practically all riveted joints are held by the friction alone, it certainly seems wrong to consider as the basis of strength, elements, such as bearing, which cannot possibly come into play until the joint has yielded.

A LOW CRIB DAM ACROSS ROCK RIVER.

By J. W. Woermann, Member of the Engineers' Club of St. Louis.

[Read before the Club, May 6, 1896.*]

The dam which is herein described constitutes one of the structures of the Illinois and Mississippi Canal, better known as the Hennepin Canal, and was built for the purpose of furnishing slack water navigation in Rock River above the Lower Rapids, which are located at Milan, Ill. The location and general engineering features of this canal were briefly described in a paper devoted to the concrete construction on the same, read before the Club about two years ago, and published in the journal of the Association for November, 1894. Since that time the four and one-half miles of canal around the Lower Rapids, together with about eight miles of slack water above the dams, or about thirteen miles in all, have been opened to navigation, and some coal traffic is being developed. During the same time eight miles have been completed on the Eastern Section, immediately adjoining the Illinois River, including the masonry for seven locks, one aqueduct and a number of minor structures. The concrete abutments for this dam or dams, as there are two sections of it, one or either side of Carr's Island, were described in the former paper, so that only the cribwork or dam proper will be considered at the present time.

LOCATION.

The determination of the best location for the dams involved a complete survey of this vicinity, including not only ordinary soundings over a considerable stretch of the river, and the taking of topography along the shores, but also the preparation of profiles, showing the elevation of bed-rock at the most feasible sites. The topography along the shores was necessary, as some of the locations required a greater or less extent of levee to protect the adjoining lands from overflow.

The location finally selected requires a dam across the south channel of Rock River, at the head of Carr's Island, 764.2 feet in length, and another dam across the north channel 598.3 feet in length, about 800 feet below the head of the island, giving a combined length of 1,362.5 feet of crest. Connecting the two dams is a levee about 1,000 feet long to protect the island from overflow at high-water.

* Manuscript received July 20, 1896.—*Secretary, Ass'n of Eng. Socs.*

DESIGN.

The general design of the dam was prepared by Major W. L. Marshall, Corps of Engineers, U. S. A., the general plan of which can be most readily seen by a glance at Plate VI accompanying this paper. It was designed for a rock foundation to withstand a maximum head of four and a half feet, and may be described as a rock-filled crib, the woodwork consisting principally of six-inch by eight-inch pine timbers laid flatwise. The main part of the dam is thirteen and a half feet in width and the apron six and one-half feet, making the total width of the base twenty feet. Immediately adjoining the cribwork above is a filling of clay and quarry refuse of about the same width as the cribwork, and rising in height to the top of the sheet piling.

The main dam and the apron are both covered with four-inch oak plank, and the up-stream face of the dam with two rows of two-inch pine sheet piling. The oak plank on the main dam are closely fitted together, making it practically water-tight, so that the vertical pressure of the water above the coping is added to the weight of the material in the dam in giving increased stability to the structure.

The coping of the main part of the dam is built on a slope, rising two feet from the sheet piling to the crest, with a view of preventing projecting limbs and other irregular objects from getting caught on the up-stream face and pounding more or less upon the coping, as is usually the case where the slope is in the opposite direction.

From the crest of the dam to the apron is a fall of three feet. The top of the apron is about six inches above extreme low-water, but at the stage at which the ice usually goes out it is covered with water, more or less, forming a cushion which prevents the ice from cutting the apron as it otherwise would. In the spring of 1895 the ice went out at an unusually low stage, with a thickness of six to twelve inches, but did no damage. The six-inch by eight-inch transverse pine timbers, projecting two inches above the level of the apron, were cut down to the level of the oak plank to some extent, but this was anticipated and was not considered important.

NORTH COFFERDAM.

The construction of the dams was in charge of Mr. L. L. Wheeler, M. Am. Soc. C. E., as Resident Engineer, with the writer as principal assistant, and Mr. Geo. T. McGee as instrumentman. The best form of cofferdam to use in shutting off the river was a matter of considerable investigation, and the contingencies and probable cost were estimated for several different styles. Inasmuch as Rock River is usually at a low stage during the summer, and as the spring of 1894 had been unusually dry, it was decided to build a simple earth embankment across each

channel with riprapping on the up-stream side to protect them from wave-wash. This plan received greater favor also from the fact that the cofferdam around the guard lock had been successfully built in this manner, and because the bed of the river was of such a nature that teams could be driven over it wherever the depth was less than three feet. As the north channel contains the deepest water, the greatest depth at that stage being about five feet, it was decided to build that dam first, and leave half of it incomplete to serve as a temporary sluice-way during the construction of the South Dam.

An area below the north abutment of this dam was stripped in April to furnish a site for a quarry, and early in June the construction of the cofferdam was commenced. The stripping from the quarry, together with the quarry refuse, formed the body of the cofferdam, while a ridge of riprap was kept in advance on the lower side to prevent the current from washing away the loose earth. While the embankment was being started from the north shore of the river, five cribs, sixteen feet square, were settled in line adjacent to Carr's Island. The cribs were built in the shallow water near the shore, by simply boring a hole in each end of each timber and dropping them over the long bolts which held the timbers together at each corner of the crib. The cribs were placed fourteen feet apart, the top covered with four-inch oak plank, and weighted down with rock and bags of sand. Six by eight-inch timbers, the ends of which were supported by the cribs, were then shoved down into the water, furnishing a length of about 130 feet to sustain the riprap from being carried away by the current. The riprap and earth cofferdam was then extended to the island, above this protection, and the flow completely shut off. The weight was then taken off the cribs and the lumber used in the construction of the permanent dam. Subsequently the riprap was removed and used for filling in the permanent structure,—this recovery of the riprap being the principal argument in favor of placing the stone on the down-stream side of this cofferdam.

The end of the cofferdam was kept about two feet above the surface of the water, the wagons being dumped while they stood on the steep slope at the end. A small amount of riprap was placed on the up-stream side, above the water-line, to protect the embankment from wave-wash. The teams returned to the shore by driving through the water on the upper side of the cofferdam. On account of the south channel remaining entirely open, the construction of this cofferdam only raised the water surface about four inches. The foot of the island was far enough down-stream to keep the backwater from coming up and interfering with the work. Low secondary cofferdams, a few inches in height, were then built below the main cofferdam, to exclude the seepage that came from the latter. The areas enclosed were from fifty to two hun-

dred feet in length, according to the irregularity of the bottom, and were kept dry by means of hand-pumps. The entire amount of material in this cofferdam, including what was in the secondary dams, was about 300 cubic yards of riprap and 800 cubic yards of quarry stripping.

FOUNDATION.

All sand and gravel, together with as much of the bed-rock as could be readily raised with a pick, were then cleared away and the construction of the cribwork commenced. Where the rock was comparatively smooth and solid, iron anchor bolts were set in cement, in holes drilled for the purpose, to which the foundation timbers were bolted so as to insure a greater factor of safety against sliding. The bolts were usually one and one-eighth inches in diameter and twenty-four inches long, but where the bottom was less firm longer bolts were used. Two bolts were generally placed in each panel, the spacing depending on whether the first course consisted of longitudinal or transverse timbers. Where the rock was loose enough to permit a trench to be picked out, six inches or more in depth, for the base of the dam, the anchor bolts were considered unnecessary. The largest pocket of clay was ten feet across, and was excavated to a depth of six feet below the river bottom before starting the cribwork. Over the three largest pockets the apron was made fourteen feet in length instead of the regular seven-foot length.

CRIBWORK.

All the timbers in the dam were six by eight inches except the top timber on the up-stream face and the top timber under the crest, which were eight inches by eight inches, and eight inches by ten inches, respectively. All of the longitudinal timbers were sixteen feet in length and were arranged so as to break joint regularly and to bring the joints within two feet of the middle of the panels. The bottom course consisted of six rows of timbers, so as to furnish more area for the support of the rock filling, and each of the succeeding courses only five, up to the level of the apron.

In laying the bottom timbers readings were taken on them at frequent intervals with a wye level so as to insure their being started at the proper grade. Where the bottom was comparatively regular the carpenters extended the work several panels at a time with common spirit levels. Throughout the work the bottom timbers were adzed to fit the irregularities in the rock so as to insure greater safety against sliding. Readings were again taken on the cross-timbers at the level of the apron, and on the eight-foot blocks near the top, and wherever the elevations exceeded the proper grades by more than a half inch

the course next following was notched down accordingly. The differences in elevation were caused mainly by the variation in thickness of the timbers. The lumber being only regular commercial stock, the thickness varied all the way from five and a half to six inches. On this account also the bottom timbers were started about two-tenths of a foot above the elevation shown on the plan so that allowance could be made for this deficiency. An absolutely level crest at an exact grade, however, was not considered of sufficient importance to warrant much additional expense in notching down timbers, so that no great refinement was attempted in this direction. The highest and lowest points on the crest of the North Dam were 130.04 and 129.91 respectively, and for the South Dam 130.59 and 130.46 respectively. The maximum difference in each case is thirteen-hundredths of a foot, and the mean elevation determined from readings taken every sixteen feet are 129.992 and 130.530, Hennepin Datum.

From the level of the apron upward the transverse timbers are of different lengths in order to properly support and reinforce the purlins, as shown on Plates V and VI. The purlins were five in number, spaced about three feet and three inches between centers. The use of the templates in marking the gains to receive the purlins is shown graphically on Plate VI and requires no further explanation.

The transverse timbers are all spaced eight feet apart except that in the course above the bottom longitudinals an extra timber fourteen feet long is placed in the middle of each eight foot panel, so as to assist in receiving the weight of the rock filling. On the down-stream face of the dam, under the apron as well as under the coping, a two-foot block is placed under each joint, to which the longitudinals are thoroughly bolted. The intention was to increase the tensile strength on that side, so that in case any part of the dam should ever be called upon to act as a beam, it would have proportionately greater transverse strength.

DRIFT BOLTS AND SPIKES.

The method of drift bolting can be seen most readily by glancing again at Plate VI. The size of all the drift bolts was three-quarter inch by sixteen inch except that ten-inch bolts were used at the bottom wherever the first course happened to consist of longitudinals, and eighteen-inch in putting on the eight by eight-inch and eight by ten-inch longitudinals. One bolt was driven at each intersection, the bolt being always started through a cross-timber. Holes were bored to the full depth of the bolts one-sixteenth inch smaller in diameter.

The four-inch oak planking on the coping and apron was fastened down with two seven-sixteenths inch by eight-inch boat spikes at each purlin, for which seven-sixteenths inch holes were bored. The first row

of two-inch sheet piling was held temporarily with 20*d* wire nails until the second row was put on, both rows being carried along together, after which they were fastened permanently with four three-eighths inch by seven-inch boat spikes per running foot, driven without boring.

ROCK FILLING.

The filling of the dam was carried on simultaneously with the crib-work, and the stone packed in between the timbers so as to obtain as much weight as possible. The filling immediately adjoining the crib-work on the up-stream side was carried along in a narrow embankment as fast as the sheet piling was put on. This permitted the rock teams to be driven up close to the sheet piling, and made it possible to throw the stone directly into the cribwork from the wagons. When the dam was nearly in the condition in which it was to be left during the construction of the South Dam, this embankment was widened by casting over material from the cofferdam, until the latter was finally allowed to break through.

TEMPORARY SLUICEWAY.

The temporary sluiceway in the North Dam, previously referred to, kept the water above the dams about two feet lower than if the dam had all been completed at one time,—and allowed the South Cofferdam to be made lower by the same amount. The saving by this plan must not be measured directly by the difference in the volume of the South Cofferdam under the two conditions, but by the fact that the average depth of water in which it was necessary to work would have been increased from about two feet to four feet, in case the sluiceway had not been used.

A temporary bracket consisting of a vertical post and two braces was set up at each panel point, as shown on Plate V. On the up-stream side of the posts, near the top, was supported a line of four-inch by twelve-inch pine wales. This brought the wales on line with the permanent sheet piling, which formed the bottom of the sluiceway. In shutting off the sluiceway subsequently, in order to complete this portion of the dam, it was necessary simply to shove the sheet piling down in front of the wale, and allow them to catch on the top of the permanent sheet piling. The vertical posts and the long braces were used in the completion of that half of the dam, and the balance of the lumber on other parts of the canal, so that there was no waste of lumber. During the construction of the South Dam this sluiceway carried the whole discharge of the river, amounting to about 2,500 cubic feet a second.

SOUTH DAM.

The construction of the South Cofferdam was commenced on July 24th, and completed on August 4th. In this case the ridge of riprap was

extended ahead of the earthen portion on the up-stream side, so as to permit the teams to return to the shore on the lower side, as the increased depth, caused by shutting off the water completely, would not permit the same plan to be used as at the North Dam. On account of the greater amount of water with which it was necessary to contend in making the final closure, ten cribs were erected adjacent to the Island instead of five. These were settled on the up-stream edge of the cofferdam. When the end of the cofferdam had been extended so as to come under the protection of the first crib, wales were placed across the spaces between the cribs and driving sheet piling was commenced from both ends of this three-hundred foot space covered by the cribs. Under this protection work on the rock and earth cofferdam was also carried on from both ends. As the ends of the cofferdam were extended part of the sheet piling was taken up and used a second time, and only in making the final closure for the last hundred feet was it necessary to double the piling. The method of dumping the wagons and the final closing behind the cribs are shown on Plate I.

When the comparatively tight embankment had been completed the weight was taken off the cribs and the lumber used in the permanent structure. Most of the clay and riprap for this cofferdam were taken from a waste pile of material that had been excavated from the lock pit at the south end of the dam.

As indicated by the borings, it was found that the foundation of this dam was not as good as the other, inasmuch as a stretch of hard clay was encountered 50 feet in length, and a bed of compact sand and gravel 120 feet in length. This was excavated to a depth of about three feet below the bed of the river, and the material used as filling above the dam. As the cribwork progressed, the V-shaped trench that remained below the apron was filled with heavy stone, as shown on Plate V.

The carpenter work on this dam was commenced on August 7th and completed August 22d, sixteen days from the time the first timber was laid. The Federal labor law, passed by Congress in 1892, prohibited us from working more than eight hours a day, without putting on a second shift, which was considered impracticable, but it did not prevent us from working on Sundays.

The construction of this cofferdam raised the water surface about two feet higher than it was during the building of the North Dam, and in order to provide a sluiceway for carrying the seepage from the cofferdam through the permanent dam, the sheet piling was omitted from one panel until the filling above the dam was all completed. The cofferdam was allowed to break through on August 24th, exactly one month from the time the cofferdam was commenced.

The rock filling for this dam was obtained considerably cheaper than

Plate I.

Plate II.

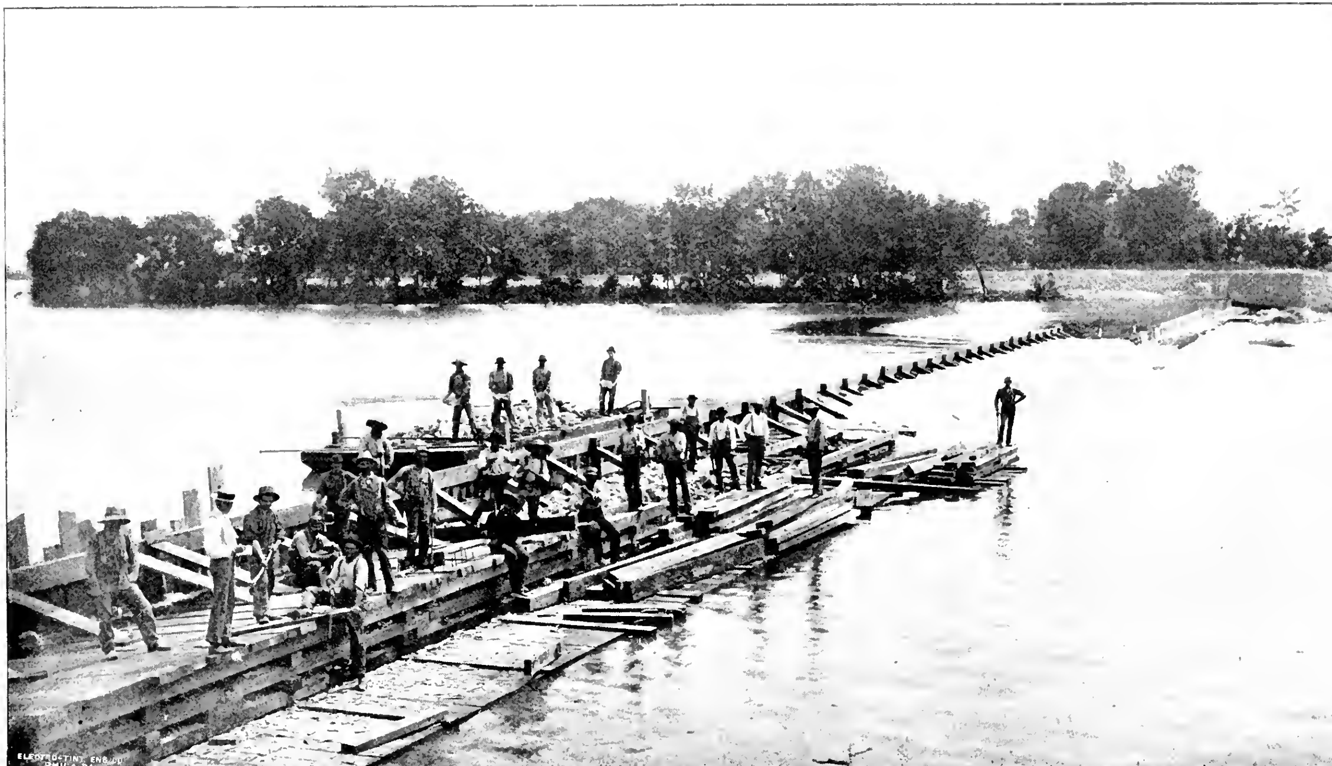
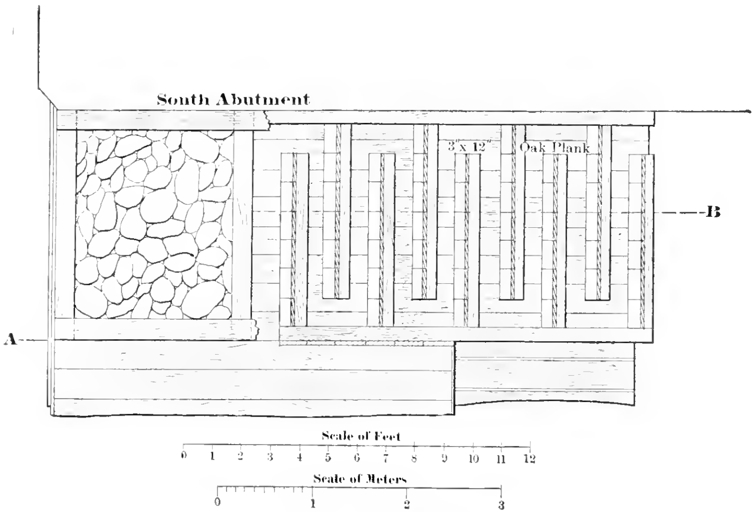
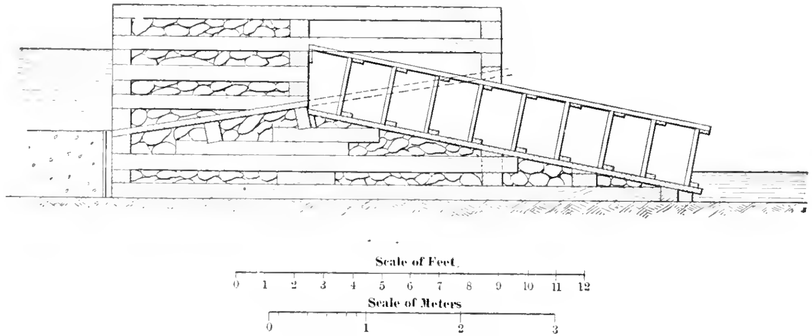


PLATE III.

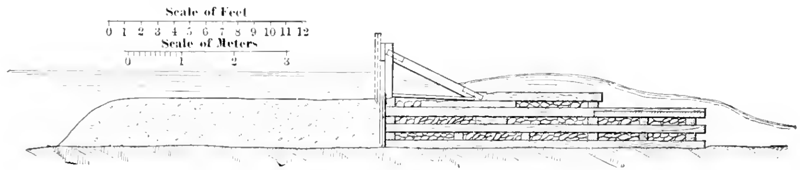
PLATE IV.



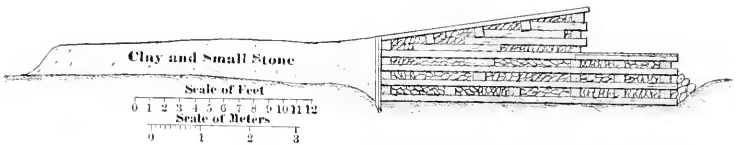
Plan of Fishway.



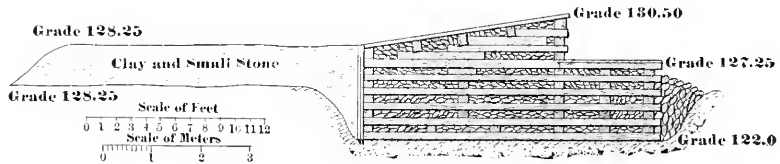
Section A-B of Fishway.



Temporary Sluiceway in North Dam.



Typical Section on Rock Foundation.



Typical Section on Gravel Foundation.

PLATE V.

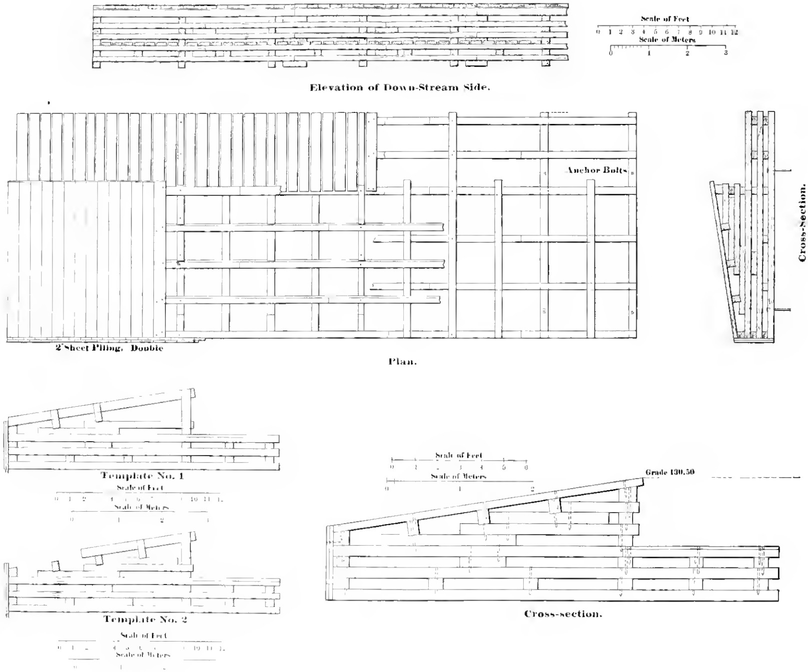

Scale of Feet
Scale of Meters
Elevation of Down-Stream Side.
Anchor Bolts
Cross-Section.
2" Sheet Piling, Double
Plan.
Template No. 1
Scale of Feet
Scale of Meters
Template No. 2
Scale of Feet
Scale of Meters
Grade 130.50
Cross-section.

PLATE VI.

for the other from the fact that on this side about 75 per cent. of the rock was readily quarried from the bed of the river without explosives.

FORCE EMPLOYED.

During the construction of the South Cofferdam the force consisted of about fourteen teams and fifty laborers. For a few days while the preparation of the foundation was being rushed the number of laborers was increased to 130.

During the erection of the cribwork the force consisted of sixteen carpenters, and about fifty laborers, about one-third of the latter assisting the carpenters in carrying timbers, boring, and driving bolts and spikes. The number of teams remained the same throughout the work. The appearance of this dam during construction is shown on Plate II, while the view presented with the water running over it, after both dams were completed, is shown on Plate IV.

COMPLETING NORTH DAM.

After the completion of the South Dam the temporary sluiceway in the North Dam was closed as previously described, and the upper part of the dam completed readily under the protection of the sheet piling. As soon as the sheet piling was in place the lower braces were knocked out, so that there was nothing to interfere with putting on the purlins. As the coping was gradually extended from the abutment, braces were put in from the waling-piece back to the top of the oak plank. This permitted the post and the remaining brace to be knocked out, as the spikes in the sheet piling were sufficient to support the weight of the waling-piece. The stone filling was thrown into the crib from a barge which was towed alongside the sheet piling. The completion of this part of the dam occupied four and a half days, including the erection and removal of the sheet piling. Plate III was taken during the completion of this portion of the dam.

FISHWAYS.

At the time the dams were built a fishway was constructed at the south end of each dam. It was found, however, that they were unsatisfactory for several reasons, and during the following summer they were modified according to the plan shown on Plate V. By increasing the number of wings from five to nine the velocity of the water was checked so that fish can readily ascend from step to step. The upper end is arranged so that the fish go out into comparatively quiet water, instead of having to jump over the crest, while at the same time the amount of water entering the fishway can be regulated to suit the stage of the river. They also comply with the theory that a fishway, in order to be

found readily by the fish, should not extend down-stream any farther than the apron of the dam. The cribs above the fishways, together with their protected position adjacent to the south abutments, are designed to protect them from ice. When the fish are running up-stream the larger ones can frequently be seen entering and leaving the fishways. By shutting off the water at the upper end, as many as sixty fish of various species have been found in it at one time, some of which have been from two to three feet in length.

TOTAL AMOUNT OF MATERIAL IN DAMS.

	North Dam. *Ft. B. M.*	*South Dam.* *Ft. B. M.*
Longitudinal timbers	47,230	73,550
Transverse "	28,350	46,950
Sheet piling	7,950	14,610
Total pine lumber	83,530	135,110
Oak plank in coping	33,540	42,840
" " " apron	15,870	19,300
Total oak lumber	49,410	62,140
Total oak and pine lumber	132,940	197,250

The total amount of lumber in both dams is 330,190 feet, B. M. The cost of the labor expended in putting this in the dams amounted to $1,914, or $5.80 per M.

The total amount of rock filling in the North Dam is 1,240 cubic yards, and in the South Dam 2,350 cubic yards, making the total for both dams 3,590 cubic yards.

AMOUNT OF IRON IN DAMS.

	North Dam.	*South Dam.*
Anchor bolts	1,010 pounds.	320 pounds.
Drift "	6,050 "	9,610 "
Boat spikes	4,750 "	6,050 "
Wire nails	300 "	400 "
Total	12,110 pounds.	16,380 pounds.

COST OF LABOR ON EACH DAM.

	N. Dam.	*S. Dam.*
Hualing material		$283 97
Building cofferdam	$729 55	1,055 34
Preparing foundation	493 30	818 04
Carpenter work on dams	948 92	964 86
Quarrying rock, filling cribs, and grading above dams	1,965 54	1,970 56
Engineering, watching, and miscellaneous	362 25	402 47
Total	$4,499 56	$5,495 24

making the total cost of the labor on both dams practically ten thousand dollars.

TOTAL COST OF THE TWO DAMS.

The total cost of the two dams, including labor and material, is as follows:

Rent of land	$ 217 40
Labor	9,994 80
Oak lumber	2,919 00
Pine lumber	3,086 60
Explosives	151 19
Drift bolts, spikes, etc.	804 98
Total	$17,173 97

The total length of the two dams being 1,362½ feet, makes the cost per lineal foot $12.60.

Bradley & Poates, Engr's, N.Y.

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EXPERIMENTS ON VITRIFIED PAVING BRICK.

BY F. F. HARRINGTON, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read before the Club, June 17, 1896.*]

ABOUT this time last year Prof. H. A. Wheeler delivered before this Club an interesting lecture on "Vitrified Paving Brick," in which the processes of manufacture, the methods of testing, and the uses of paving brick were very thoroughly described. The speaker reviewed the methods of testing and the results of many experimenters, and explained many ways of combining the results of the various tests in order to show the relative merits of different kinds of paving material. Although the tests given were made by reliable men, the chief objection to them as a whole is that the methods employed were so different that the results, from a scientific standpoint, are inconclusive and not comparable. Only a short time ago, also, Prof. J. B. Johnson addressed the Club on "The Resistance to Crushing of Brittle Materials," including vitrified brick, and in this address the results of tests by Bauschinger, at Munich, were exhibited and many interesting relations shown.

About a year ago the Water, Sewer and Street Commissioners of this city established a testing laboratory, where all the material used by the city could be tested, instead of each department having its own testing done, as was formerly the custom. The use of vitrified brick had already been resorted to in the construction of alleys in the city, and its extensive use for street paving was about to follow. The question of determining the quality of the material therefore became an

* Manuscript received July 8, 1896.—*Secretary Ass'n of Eng. Socs.*

important one, and the laboratory was equipped with suitable apparatus for some of the essential tests.

A review of the past will show that vitrified paving brick has been used for several years in many cities and towns in the United States, and in most cases no laboratory tests were made, while in other cases reports of tests show them to be extremely crude and variable. Take for example the abrasion test. The material of construction of the rattler may be cast or wrought iron, steel, wood, or some combination of these materials; the size ranges from 12 inches to 60 inches in diameter; the speed from 200 to 10 revolutions per minute; the charge of bricks for the test varies from 5 to 40, usually composed of samples of different manufactures; sometimes whole bricks are used, and at other times cubical specimens are taken from them for test; the size of the abrading material ranges from that of shot to scrap iron pieces weighing over five pounds each; sometimes billets or blocks of wood are used as cushions for the bricks, and frequently granite, trap rock and other kinds of stone are introduced to furnish a comparison between brick and other paving material. The duration of the test varies from twenty minutes to three hours, and often an intermediate weighing is made, the loss during the first period of the rattling process, when the edges are defaced, being neglected, and that during the second period being taken for the loss due to abrasion. Specifications in different localities are therefore variable in their requirements and show a lack of information on the subject. Thus, in some cases, a few special tests must be employed, and in others, different ones, but it is very seldom that well-defined requirements are stated covering the essential tests. The paving-brick industry is now, however, developing rapidly, and the material is being extensively used in the residence districts of many of the largest cities, so the importance of an investigation of this subject is therefore apparent.

In 1895, at its annual convention, the National Brick Manufacturers' Association appointed a committee for the purpose of recommending for adoption a standard series of tests on vitrified paving brick and the methods of making them. This Commission is now actively engaged in the investigation of the subject. The first meeting was held August 1, 1895, at which time a preliminary standard method of making the various tests was agreed upon as a basis of conducting the necessary experiments. The experimental work was also apportioned between the members, in order to make the greatest haste in the preparation of the final report. The Commission is composed of engineers and brick manufacturers, and its recommendations, it is expected, will therefore be generally accepted.

It is intended to examine vitrified paving brick in this laboratory by means of the following tests: The rattler, absorption, cross-break-

ing, crushing, freezing, specific gravity and hardness. New machinery is being obtained for making all these tests. The Water Commissioner, Mr. M. L. Holman, has designed and built a new hydraulic testing machine for cross-breaking brick, having a capacity of 20,000 pounds, and has just completed the design of an hydraulic machine for crushing brick and other materials of construction, having a capacity of 1,500,000 pounds. This will be the most powerful crushing machine in the West.

The following are the results of the rattler and absorption tests made up to this time:

IMPACT AND ABRASION TEST.

The rattler test is considered by most engineers to be the most important test for vitrified brick. It is a measure of the toughness of the material, when laid in the pavement, to withstand the blows of horses' hoofs and the wearing action of the wheels of vehicles.

The tumbling barrel used for making the following tests is made of cast iron. It is polygonal in form, having 15 staves, and its dimensions are approximately 24 inches in diameter and 42 inches long. It revolves on trunnions. Within the barrel is a cast-iron partition at right angles to the axis by means of which the length can be varied. The barrel is operated by a constant speed electric motor, through a main shaft, counter-shaft and gear wheels.

The vitrified paving brick used for the tests were made of pure shale, worked by the stiff mud process, and burned in down-draught kilns. Five hundred well-burned samples were selected from one kiln, with the view of obtaining the most uniform specimens possible. They are repressed brick and have rounded edges. The dimensions are $8\frac{1}{4}$ x 4 x $2\frac{1}{2}$ inches. The volume of one brick is therefore $82\frac{1}{2}$ cubic inches, and the weight is slightly less than seven pounds.

The results of the tests are shown in Figs. 1, 2, 3 and 4.

Fig. 1.—An arbitrary length of barrel of 30 inches and speed of thirty revolutions per minute were chosen to begin the work. Five per cent. of the volume was then filled, requiring eight bricks, and the percentage of loss calculated after forty and eighty minutes' tumbling. In the same manner the barrel was filled to 10, 15, 20 and 25 per cent. of its volume, using 16, 24, 32 and 40 bricks respectively, and the percentages of loss calculated as before, after forty and eighty minutes' tumbling. The maximum percentage of loss was thus found to be when the barrel was filled to 15 per cent. of its volume.

Fig. 2.—For the experiments shown in Fig. 2, the cast-iron partition in the barrel was moved so as to make the length successively 12, 21, 30 and 39 inches, and for each test 15 per cent. of the respective volumes were filled, requiring 10, 17, 24 and 31 bricks for the charges.

The percentage of loss was calculated in each case after tumbling forty and eighty minutes. It will be seen that the percentage of loss is practically independent of the length of the barrel, when 15 per cent. of its volume is filled.

Fig. 3.—For these tests a length of barrel of 30 inches was chosen, as in the tests in Fig. 1, and 15 per cent. of the volume of barrel, or twenty-four bricks, were tumbled in each experiment. The barrel was run at speeds of 20, 25, 30, 35 and 40 revolutions per minute by changing the pulley on the main shaft, and the percentage of loss was calculated after 10, 20, 30, 40, 60 and 80 minutes' tumbling for each test. It will be seen that the percentage of loss continues to increase with the increase of speed and at a more rapid rate. This evidently shows that the construction of the barrel is such that a speed of forty revolutions per minute is not sufficient to cause the bricks to revolve around the axis of the barrel, nor is it sufficient to carry the bricks up to a height that will produce the greatest loss from the impact of the bricks upon one another, due to their fall. The curves indicated by 20, 30 and 40 minutes' tumbling are quite regular, while those of 10, 60 and 80 minutes' tumbling are irregular. The irregularity in the case of 10 minutes' tumbling may be accounted for from the fact that the edges of the specimens are being knocked off during this time, while that of 60 and 80 minutes may be caused by the disintegration of the bricks from the length of time that they have been subjected to the test.

Fig. 4.—In Fig. 4 the same tests are recorded as those shown in Fig. 3. The abscissa is here changed, however, to time of tumbling, while the speeds in revolutions per minute are written on the curves. These curves may be called "characteristic rattler curves" for the material at different speeds. They show the greatest loss to be during the beginning of the tests, when the edges are being defaced, and in general the percentage of loss is less with equal successive intervals of time during the continuance of the tests.

In making the preceding experiments, the bricks for each charge were weighed in bulk on a scale reading from ¼ pound to 250 pounds. The time of tumbling for all the tests was observed to the second. The speed of the barrel was so controlled that it did not fluctuate from that recorded a single revolution during the progress of the work. The most striking feature noticed was the uniformity of the brick tested. Thus the total weight of any 24 of the 500 bricks weighed, taken at random, did not vary more than a half pound. It was also found that the weight of any ten bricks did not vary more than one pound from that of any other ten bricks, when taken from the rattler at the completion of any particular test. This not only shows the brick to be very uniform, but also that the rattler is constructed so as to give results that are strictly uniform and comparable.

The results are:

(1) The maximum percentage of loss is obtained when the barrel is filled to 15 per cent. of its volume with brick.

(2) The percentage of loss is independent of the length of the barrel, when the foregoing condition is fulfilled.

(3) The percentage of loss increases at a more rapid rate than the speed from twenty to forty revolutions per minute.

(4) The percentage of loss decreases with equal successive intervals of time up to eighty minutes' tumbling.

A study of the results leads to the following recommendations for a standard rattler test.

Figs. 3 and 4 show that it is necessary first to choose a definite speed for running the barrel. A suitable speed would be thirty revolutions per minute, since this gives about the average circumferential speed of rattlers in general use. Then obtain characteristic rattler curves as shown in Fig. 4 for brick of each manufacture at the above mentioned speed. When these characteristic curves are drawn, it will only be necessary to find the percentage of loss after tumbling samples a given time for the test, or in other words to determine a single point on the curves. A suitable length of time for continuing this test would be forty minutes, since from Fig. 4 it appears that the edges of the brick suffer the greater loss from impact during the first twenty minutes, while during the next twenty minutes the exposed surfaces are abraded.

Having decided upon a definite speed and a definite time of tumbling, any one of the following three methods may be chosen for the standard test:

(1) Fill the barrel to 15 per cent. of its volume with the brick to be tested, adjust the partition in accordance with the number of brick on hand and tumble at the adopted speed for the chosen length of time. For this method it would be advisable to always test about fifteen bricks and move the partition according to their size. Not less than ten bricks should be tested.

(2) Clamp the partition at a definite position in the barrel, fill to 15 per cent. of its volume with the brick to be tested, and tumble at the required speed for the chosen time. For this method a good position for the partition would be in the middle of the barrel, making two chambers 21 inches in length, so that two tests could be made simultaneously. To make the test in this way, it would be necessary to use about seventeen bricks of standard size ($8\frac{1}{4}$ x 4 x $2\frac{1}{2}$ inches) or about thirteen of block size (9 x 4 x 3 inches).

(3) With partition clamped as in (2) put in the rattler the five or ten sample bricks to be tested and fill to 15 per cent. of volume of chamber with a selected uniform standard brick, kept in the testing

laboratory for that purpose, and tumble at the required speed and length of time.

RATTLER EXPERIMENTS WITH CAST-IRON BLOCKS.

A method of making the rattler test prevalent in some places has been to tumble five sample bricks with ten cast-iron blocks, each weighing about six pounds, for thirty minutes and determine the percentage of loss. In order to examine the reliability of this test, fifteen "unit bricks" as described above, were selected, five of which were tumbled with ten cast-iron blocks three successive times under the above conditions. The length of the barrel was 21 inches and the speed thirty revolutions per minute. Fig. 5 shows the results, the numbers on the curves giving the order of the tests. It will be seen that this method gives no characteristic curve such as we obtained when only bricks were rattled, and it is therefore apparent that the method represented in Fig. 5 is not a good one.

THE ABSORPTION TEST.

The absorption test is considered a very important one for paving brick for the reasons:

(1) For any particular brick, the percentage of absorption is an index to the degree of its vitrifaction.

(2) From a sanitary standpoint, it indicates the relative avidity for the retention of refuse matter, the evaporation of which pollutes the atmosphere with noxious gases.

(3) It furnishes a means of determining the possibility of the disintegrating action of frost.

The oven for drying the brick was designed for the purpose. It is made of galvanized iron lined throughout with asbestos. It is divided by a partition in two apartments, each 15 inches wide, 30 inches high, and 26 inches deep, and alike in every respect, so that only one side of oven need be described. There are four sliding grates, each holding fifteen standard size bricks, or sixty in all, and the full capacity of oven is 120. The heat is supplied by a Bunsen burner placed in the center of the bottom, the mixture of air and gas passing through numerous small holes of a special cap on the burner, and the flame impinges on an iron plate below the grates, thus heating the oven uniformly. The temperature is regulated by a damper in the flue, and read on a thermometer in the top of the oven.

The results of the drying tests are shown in Figs. 6 and 7. The temperature of the oven varied from 220° to 240° F. The makers of the bricks tested are designated by letters on curves, as follows:

(*a*) Alton Paving Brick Co., Alton, Ill.

(*b*) St. Louis Pressed Brick Co., Glen Carbon, Ill.

(*c*) Standard Paving Brick Co., St. Louis, Mo.
(*d*) Purington Paving Brick Co., Galesburg, Ill.
(*e*) Barr Clay Co., Streator, Ill.
(*f*) Townsend Paving Brick Co., Zanesville, O.
(*g*) Moberly Brick, Tiling and Earthenware Co., Moberly, Mo.
(*h*) Galesburg Paving Brick Co., Galesburg, Ill.
(*k*) Galesburg Brick and Terra Cotta Co., Galesburg, Ill.
(*l*) Royal Paving Brick Co., Canton O.

The average of two bricks of each kind was obtained for the curves: For Fig. 6, the bricks, as received from the makers, were dried in the oven for one week. For Fig. 7, these same bricks, when taken from the oven, were immersed in water twenty-four hours, and the drying process repeated for the same length of time. These two series of tests, it is thought, cover the conditions of the state of moisture of brick likely to be received at the laboratory for tests.

Figs. 8, 9, 10, 11, and 12 show results of the absorption tests. In Fig. 9, the absorption curves of Fig. 8, for the first three days in water, are shown on a larger scale. The figures on the curves of the plates represent bricks from the following manufacturers:

(1) Alton Paving Brick Co., Alton, Ill.
(2) St. Louis Pressed Brick Co., Glen Carbon, Ill.
(3) Standard Paving Brick Co., St. Louis, Mo.
(4) Purington Paving Brick Co., Galesburg, Ill.
(5) Barr Clay Co., Streator, Ill.
(6) Wabash Clay Co. (Poston Block), Veedersburg, Ind.
(7) Des Moines Paving Brick Co., Des Moines, Iowa.
(8) Townsend Paving Brick Co., Zanesville, O.
(9) Mack Paving Brick Co., Pittsburgh, Pa.
(10) Moberly Brick, Tiling and Earthenware Co., Moberly, Mo.
(11) Imperial Paving Brick Co., Canton, O.

Three uniform samples of each of the above kinds of brick were selected. They were dried in the oven for forty-eight hours. Two bricks of each kind were immersed whole. The results are shown in Figs. 8 and 9. Both ends of the third brick of each kind were removed, leaving about half bricks with two surfaces from interior exposed to absorb water. These results are shown in Fig. 10. Also, a small piece from the interior of the third brick of each kind, weighing about 25 grammes, was tested, the results being shown in Fig. 11. The temperature of the water in which the bricks were immersed averaged about 60° F. The water on the surface of each specimen was removed with a dry cloth before weighing. The whole and half bricks were weighed on a balance to the nearest gramme. The small pieces were weighed on a chemical balance.

RESULTS OF ABSORPTION TESTS.

Figs. 6 and 7 show that it requires four days to thoroughly dry vitrified brick when subjected to a temperature ranging from 220° to 240° F. under all usual degrees of moisture, and that in forty-eight hours they are practically dry. Thus, 94.1 per cent. of the whole amount from the bricks in normal state of moisture was evaporated in two days, and 95 7 per cent. of the whole amount contained in the samples previously immersed for twenty-four hours was driven off in two days.

Figs. 8 and 10 show that both whole and half bricks continue to absorb water up to twenty-four weeks, at which time the experiments were discontinued. For practical purposes eight weeks would be required to soak them. The percentage of absorption of the half bricks ordinarily exceeds that of whole bricks of the same manufacture. Thus at twenty-four weeks' immersion the percentage is greater for half bricks than for whole ones, except in numbers 3, 6 and 10. The average increase of half over whole bricks after soaking twenty-four weeks is 16.5 per cent.

Fig. 11 shows that the small pieces continue to absorb up to eight weeks, and also that the percentage of absorption of small pieces in eight weeks exceeds that of half bricks of the same manufacture except in the case of number 8, and that of whole ones of Fig. 8 without any exception. The average increase of small pieces over half bricks in eight weeks is 47.3 per cent , and over whole ones in the same time 66.1 per cent.

Fig. 12 shows the average absorption curves of whole bricks, half and small pieces found from Figs. 8, 10 and 11.

A study of the figures suggests the following method for a standard absorption test. Let about ten samples of the bricks to be tested be dried in the oven for at least two days. Then immerse in clear water and obtain characteristic absorption curves for each manufacture as in Fig. 8 for a length of time of eight weeks. Rattled bricks should be used for these tests, since the preceding experiments show that a higher percentage of absorption is obtained when surfaces from the interior are exposed. Furthermore, this method conforms better with the conditions of actual service, since it is only a short time after the bricks are laid in the pavement before some of the exposed surfaces are worn away.

When the characteristic absorption curves of various kinds of brick have been obtained, it will only be necessary to immerse the samples, the characteristic absorption curve of which is known, for any convenient length of time, and obtain the percentage of absorption for that time.

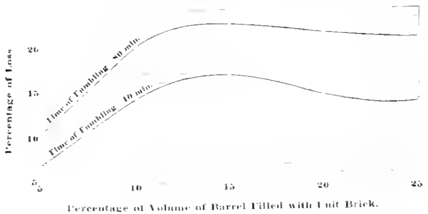

Fig. 1.

Diameter of barrel, 24 inches.
Length of barrel, 30 inches.
Revolutions per minute, 30.

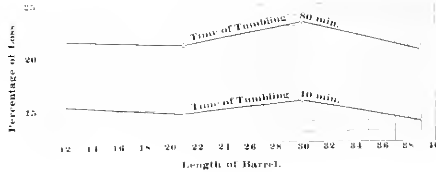

Fig. 2.

Diameter of barrel, 24 inches.
Revolutions per minute, 30.
15 per cent. of volume of barrel filled with unit brick.

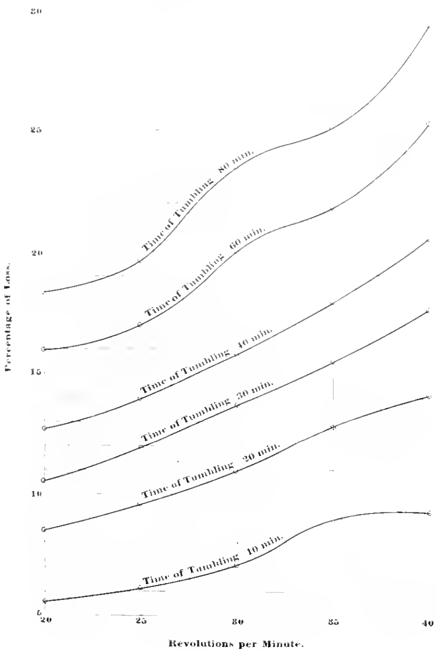

Fig. 3.

Diameter of barrel, 24 inches.
Length of barrel, 30 inches.
15 per cent. of volume of barrel filled with unit brick.

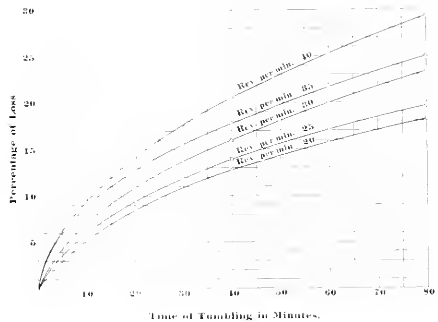

Fig. 4.

Diameter of barrel, 24 inches.
Length of barrel, 30 inches.
15 per cent. of volume of barrel filled with unit brick.

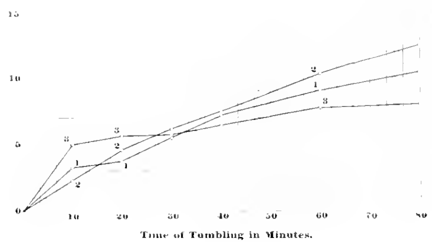

Fig. 5.

Experiments with cast iron blocks in rattler. Brick and 10 cast iron blocks.
Diameter of barrel, 40 inches.
Length of barrel, 21 inches.
Revolutions per minute, 30.
Charge for each test, 5 unit.

PLATE I.

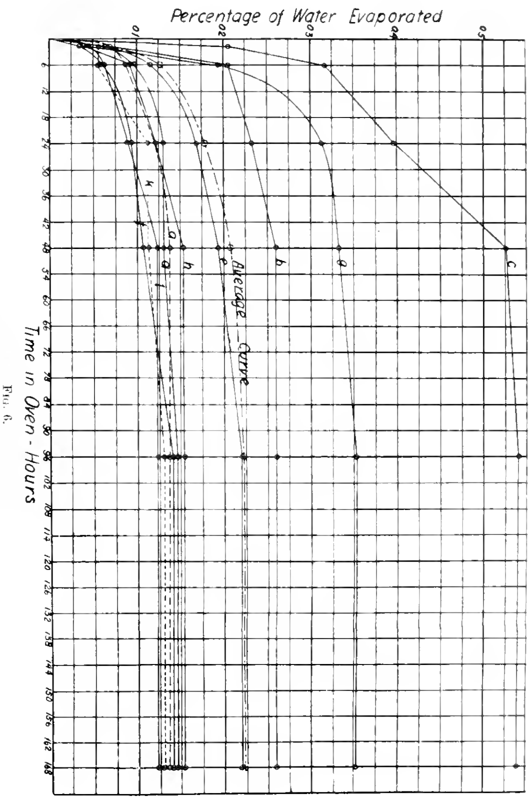

Fig. 6.

Drying Tests. Normal moisture. Each curve is the average of two bricks. Reference letters marked on curves.
Temperature of oven, 220° to 240° F.

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venient length of time, and obtain the percentage of absorption for that time.

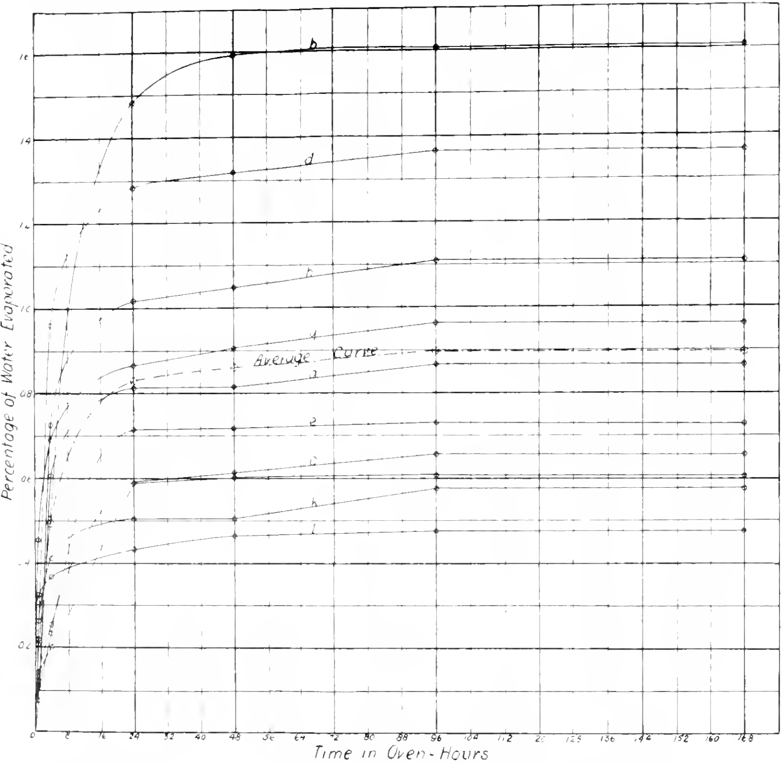

FIG. 7.

Drying Tests. Immersed in water twenty-four hours. Each curve is the average of two bricks. Reference letters marked on curves. Temperature of oven, 220° to 240° F.

PLATE 11.

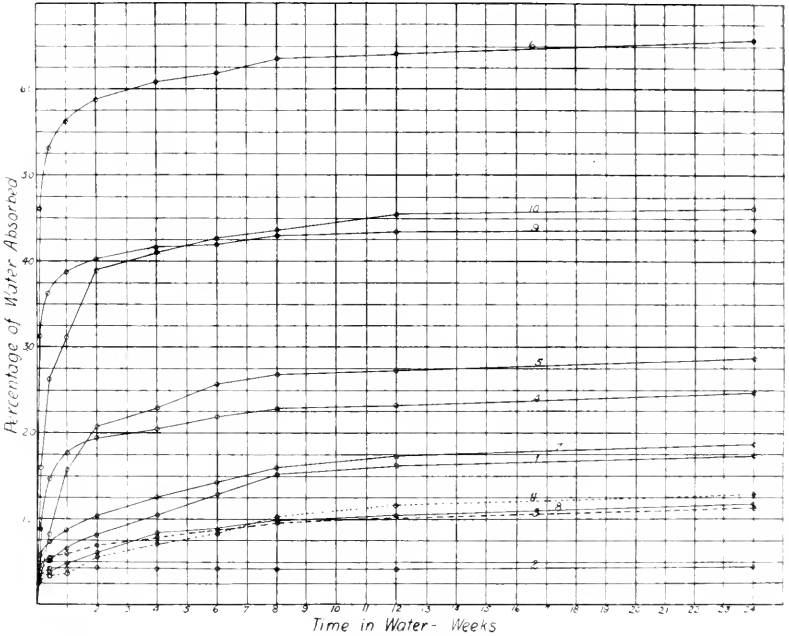

FIG. 8.

Absorption Tests. Whole bricks tested. Each curve is the average of two bricks. Reference numbers marked on curves.

PLATE III.

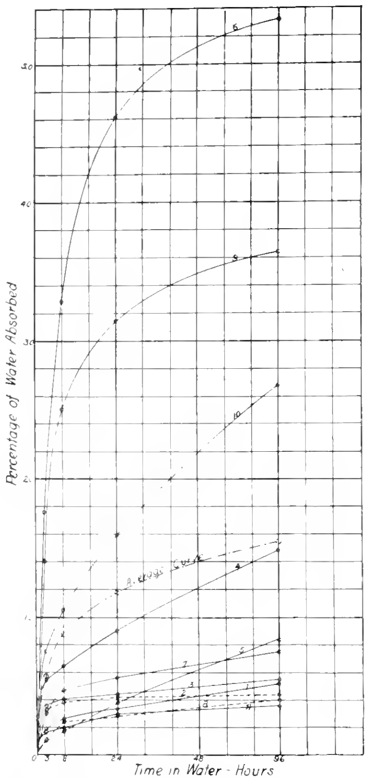

FIG. 9.

Absorption Tests. Whole bricks tested. Each curve is the average of two bricks. Reference numbers marked on curves.

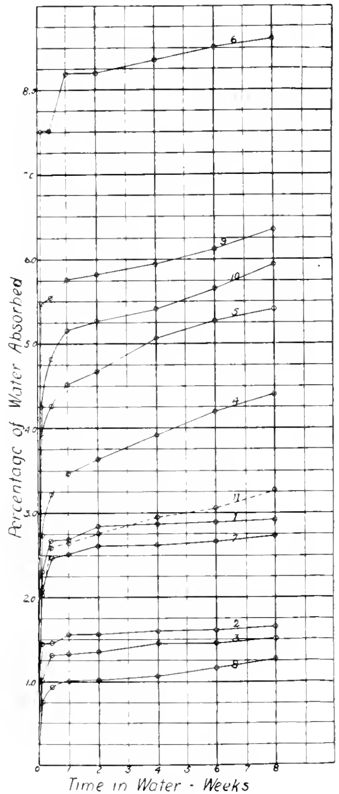

FIG. 11.

Absorption Tests. Small pieces from interior tested. Each curve represents one piece. Reference numbers marked on curves.

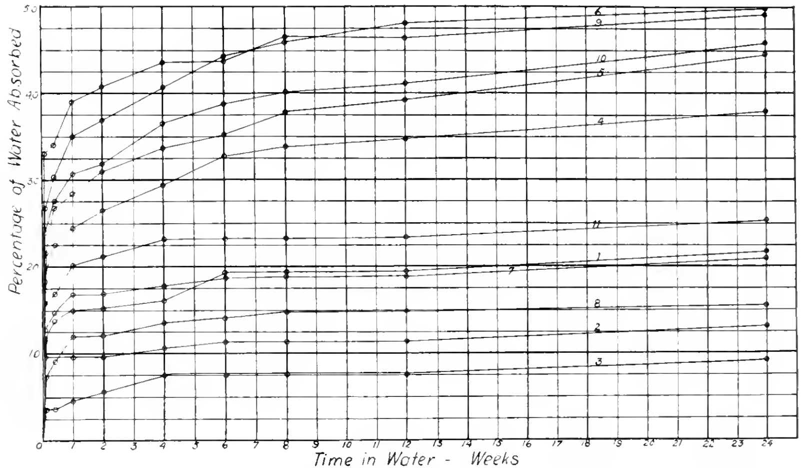

FIG. 10.

Absorption Tests. Half bricks tested. Both ends of each brick removed, leaving two surfaces from interior exposed. Reference numbers marked on curves.

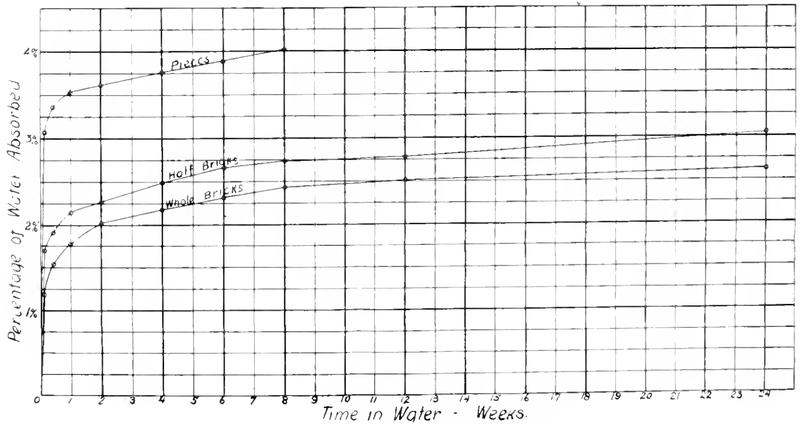

FIG. 12.

Absorption Tests. Resulting average curves of whole bricks, half bricks and small pieces.

THE CONDITIONS NECESSARY FOR EQUALITY OF VELOCITY IN PARTICLES SETTLING THROUGH LIQUIDS.

By Luther Wagoner, Member of the Technical Society of the Pacific Coast.

[Read before the Society, August 7, 1896.*]

Under the title "On the maximum velocity acquired by small bodies falling in water and glycerine," the writer published a paper in *Proceedings Tech. Soc. Pac. Coast,* March, 1888, wherein certain conclusions and empirical formulas were presented differing from the views previously held, and as the question is one of practical importance, especially in the dressing of ores and the separation of bodies by air or water, the writer has been induced to take up the subject again.

The published results of Prof. Richards, A. I. M. Engrs., Vol. xxiv, furnish data much superior to anything previously had, and, as his paper may easily be found, only a short abstract of his methods will be given. Thirteen kinds of minerals were experimented with. They were first assorted upon sieves into different sizes ranging from 10–12 to 120.140 mesh. The diameter of each sieve aperture was carefully measured and the diameter of the ore grain is taken as a mean between the sieves passing and those rejecting the grain. Fifty grains or particles of sized mineral were next dropped into a vertical glass tube, and the time required for 90 per cent. of the grains to pass two wires eight feet apart gives data for finding the mean velocity; the experiment was repeated ten to twenty times for each size, and the mean for all was adopted. We thus have data connecting the diameter or mean sieve opening and the maximum velocity of fall in the water. To have been complete the data should have given the average weight of a grain of each mineral. The immediate object of this discussion is to examine the facts about grains under one millimeter size, and the data of Prof. Richards has all been reduced from inches to millimeters, the *m.m.* being taken as unit for diameter x. and velocity equal v.

METHOD OF DISCUSSION.

Referring to Fig. 1, where the diameters x of the grains are shown as abscissæ and the velocities v as ordinates, it is required to find an equation connecting v with x and which will be reasonably correct for diameters

* Manuscript received August 13, 1896.—*Secretary, Ass'n of Eng. Socs.*

smaller than the lowest values of $x = 0.1171$ mm. or from $x = 0$ to $x = .1171$. The impelling force is gravity and the weight of the body is a function of its diameter. The retarding forces are the cross-sectional area and perhaps the surface, but both are functions of the square of the diameter. The equation for uniform motion may be written

$$v = k\sqrt{\frac{x^3}{f.x}} \qquad \text{(Eq. 1)}$$

where v = velocity in mm., x = diameter in mm. of the opening in the

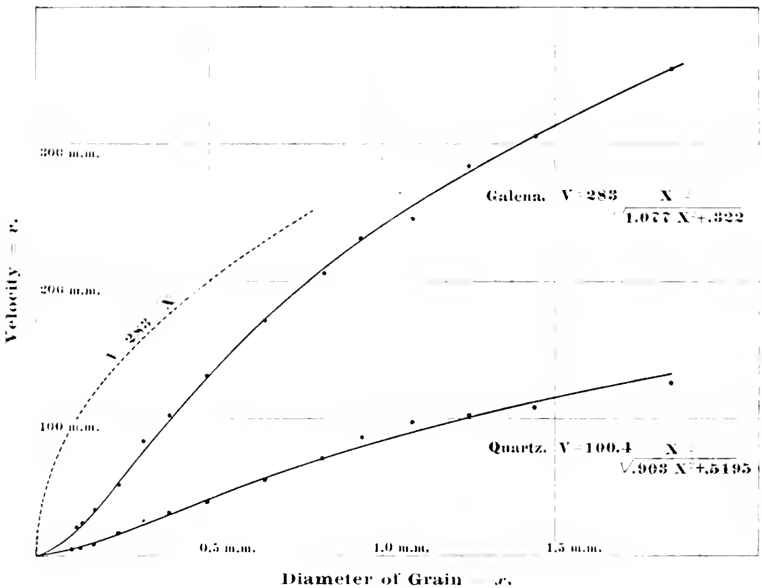

Fig. 1.

sieve. k is a general coefficient and $f.x$ is considered the unknown quantity and is found

$$f.x = \frac{k^2 \; x^3}{v^2} \qquad \text{(Eq. 2)}$$

v and x being known, k has been found as follows: Assume the various values of k to be proportional to the area of the curve shown in Fig. 1, or, what is the same,

$$\frac{k}{k_{\prime}} = \frac{\text{sum of } v}{\text{sum of } v_{\prime}}$$

A reduction of the experiments of Pernolet (vide *Annales de mine*, 1853, p. 144,) on coal, quartz, and galena 3 mm. to 30 mm. diameter combined with some experiments of the writer, gives the value of k for galena where x is the sieve aperture, equal $k = 283$, from which

all the other values of k for the different minerals become known. Substituting the proper value of k and solving the equation (2) for its 14 diameters, there result 14 values of $f.\,x$. Several formulas were tried to find an equation for the denominator, and the simplest one $f.\,x = (a\,x^2 + b)$ was adopted. a and b were found as follows: let s and $s_{\prime}$ be the sums of the first and second sets of seven of x^2, and F and $F_{\prime}$ the corresponding sums of $f.\,x$, then

$$\begin{array}{l} a\,s + 7b = F \\ a\,s_{\prime} + 7b = F_{\prime} \end{array} \text{ and } a = \frac{F - F_{\prime}}{S - S_{\prime}}$$

This method of treatment gives equal weight to each of the observations. The general result of the investigation points to an increase in value of b for diameters below 0.2 mm., probably of the form $\frac{B}{C + f\,x}$. But as the data relating to form, surface and weight, in terms of diameter, are lacking, it is useless to attempt more approximate formula.

FINAL EQUATION.

$$v = k \frac{x^{\frac{3}{2}}}{\sqrt{a\,x^2 + b}}$$

making x large, b can be omitted, and

$$v = k_{\prime} \sqrt{x}$$

which is the ordinary equation as given in text-books; making x. small, the value $a\,x^2$ may be omitted, and then

$$v = k_{\prime\prime}\,x^{\frac{3}{2}},$$

a result which accords with the facts as well as with the theory, because it is clear that very small bodies must remain suspended in the fluid ($v = 0$), hence the exponent must be greater than one. Were the old formula correct, a body whose diameter was dx would have a finite velocity.

The above equation appears to hold for diameters as small as $x =$ 0.0001 mm. Dr. Barus (*U. S. Geolog. Survey Bulletin* 39) assumes Sp. Gr. quartz, clay, etc., 2.50, and from rate of observed subsidence computes for

$x = 0.0001$ mm. $t.$ 15° $C.$, $v = 0.0000278$ mm.
$t.$ 100° $C.$, $v = 0.000556$ "

The above formula does not consider temperature, and gives $v =$ 0.000139 m m., a result fairly in accord with that of Dr. Barus.

The following table shows the value obtained from a discussion of eight of the thirteen minerals given in the table quoted:

Minerals.	Sp. Gr.	k.	a.	b.	(a. + b.)
Anthracite	1.473	25.36	.7815	.6267	1.4082
Quartz	2.640	100.4	.9030	.5195	1.4125
Pyrrhotite	4.508	140.1	.5248	.9159	1.4407
Chalcocite	5.334	140.5	.6396	.7902	1.4298
Antimony	6.706	191.4	.8799	.5485	1.4284
Wolframite	6.937	205.5	.9034	.4887	1.3921
Galena	7.586	283	1.0770	.3220	1.3990
Copper	8.479	187.6	1.0630	.3510	1.4140

The mean value of $(a + b)$ is 1.4156, which is nearly the same as $\sqrt{2}, = 1.4142$. This close coincidence of value as well as the more important fact of $(a + b) =$ constant, has a significance that the writer is unable to grasp, and should lead to renewed experiments upon spheres whereby the weight would be known and the influence of form would be constant.

The relation $\frac{v}{v_{\prime}}$ is not a constant for any two minerals, unless a and b are the same, for instance making x large and small in the case of galena and quartz.

$$x \text{ large, } \frac{v}{v_{\prime}} \frac{\text{galena}}{\text{quartz}} = 2.581 \text{ lowest value of ratio.}$$

$$x \text{ small, } \frac{v}{v_{\prime}} \frac{\text{galena}}{\text{quartz}} = 3.58 \text{ highest value of ratio.}$$

Having shown that the law of velocities is greatly changed for small values of x, it is suggested that it is probable that a similar modification will be found of the law governing the settlement of fine particles upon inclined planes (Vanners, canvas, etc.), and as perhaps more than 80 per cent. of all the ore stamped is under ¼ mm. diameter, it seems to the writer that there is an excellent field here for original investigation by the various mining schools, of the laws governing the separation of small bodies under ¼ mm.

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WATER SUPPLY AND SEWERAGE AS AFFECTED BY THE LOWER VEGETABLE ORGANISMS.

BY THE LATE CLARENCE O. AREY, C.E., M.D.

[Read before the Civil Engineers' Club of Cleveland, June 9, 1896.*]

IN taking up this subject, regarding the effect of lower vegetation upon our water and sewerage, it will first be necessary to study the nature and life-work of these minute organisms which are found everywhere, and to establish their place in the circle of the varied forms of life.

Man lives either upon other animals or upon vegetables. These other animals that furnish food for man live either upon vegetables or upon herbiverous animals dependent upon vegetable life. All animal life is therefore dependent upon vegetation for its existence. Upon what, then, does the vegetable life with which we see ourselves surrounded depend? It depends upon the gases in the air and in the soil in which it is developed. Water is part of the food of all life and it is not necessary to consider it in differentiating the various forms.

What furnishes the constant supply of the elementary gases upon which the higher forms of vegetable life depend? The life-work of the lowest forms of vegetation is to supply these gases. The bacteria, the yeasts, and the moulds do this work. They take dead organic matter as their food and reduce it to its original elements, which are mostly gases. Without them, all dead matter, unless destroyed by fire or cauterizing chemicals, would remain forever in the exact condition that it was in when death took place. When the Egyptians mummified their dead, they simply destroyed all of these organisms of decomposition. We are

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all familiar with the fact that plants will not grow on fresh manure. This is simply because the bacteria have not yet reduced it to the elements necessary to feed the plant. It is also probable that the heat, produced by the chemical changes instigated by the bacteria, acts deleteriously upon the plant. The pea and the bean contain a considerable percentage of nitrogen, and upon investigating the roots of these plants we find that they are covered with a species of bacteria whose function it is to produce nitrogen. Clover is similar, and farmers have planted their fields with clover in order to render the soil more rich, that is, to replace the nitrogen that had been exhausted from the ground. Lately the experiment of inoculating the soil with nitrogen-producing bacteria has been made.

Now, as to the structure of the bacteria, yeasts, and moulds. The bacteria are the lowest forms of vegetable life that we have. They consist of single cells, and their function as a class is to reduce dead matter to its original elements. They are not all engaged in this work, however. Some are parasitic and live upon other forms of life. We all of us have our skins covered with a variety called staphylococcus epidermatis albus, and discovered by Dr. Robb, formerly of Johns Hopkins University, but now of Cleveland. Of those that are parasitic in their nature, certain ones eliminate a poison which is deadly to the host, that is, to the person or animal upon which they happen to find an abiding-place. Right here comes the all-important point regarding bacteria; namely, how they produce disease. All life requires food; all life gives off excretions. All bacteria absorb food; all bacteria excrete other matter. The comparatively few disease-producing bacteria excrete poisons more deadly quantitatively than any known chemical poisons. These poisons separated from the bacteria will produce the same disease as the bacteria themselves, but do so more quickly because the living bacteria require time to multiply until they are numerous enough to produce a poisonous quantity of their excretions before the symptoms of disease show themselves. These same poisons diluted sufficiently, as in drinking water, may after a time render the person drinking the water incapable of taking the disease they produce when given in poisonous quantities. The poison-producing bacteria are the ones that we wish to keep out of our water supply, out of our houses, and out of our sewers.

The yeasts are slightly larger organisms and contain a nucleus. They are generally gas producers.

The moulds are slightly higher up in the vegetable scale; they branch and have fruit.

The yeasts and moulds are perhaps antagonistic to the bacteria.

The greatest enemy of bacteria is sunlight. If we take two sterile

gelatine plates and inoculate both with the same species of virulent bacteria, and expose one for half an hour to direct sunlight, and do not expose the other, the result will be that the exposed plate will contain no growth whatever, while the one not exposed will have a luxurious growth of the inoculated bacteria upon its surface.

In taking up the subject of water supply, let us first consider a river town. Suppose that a town is located on and takes its water supply from a river and that ten miles up the river is a small town which discharges its sewerage into the river, the question which at once arises is, will the health of the lower town be good? The answer to this question will depend entirely upon the amount of sewerage discharged by the upper town in proportion to the distance between the towns and the size of the river. Let us leave out the question of chemical waste and consider only the effect of the disease-producing bacteria that are carried in sewerage.

The sewage, when small in quantity, is discharged into the river and is immediately diluted with the river water. It is tumbled over and exposed to the sun, and at every tumble thousands of bacteria are destroyed. The bacteria are filtered through the green slime growing in the rivers, going to meet their death in the filtration, till, at the end of three or four miles, the water, upon examination, is found to be pure enough for drinking purposes. But if the sewage is once allowed in the river there is no limit to its quantity, and it soon gets beyond the power of the combating agencies of nature. As to the length of time that bacteria will live in water when in contact with the combating agencies the data is not exact. In some experiments they have died out in a few days from the time of their introduction into the water, while in others they have persisted for several weeks. But, on the whole, it is safe to say, if all source of infection is cut off from a body of water, that it will entirely purify itself of disease organisms inside of a few months.

In the investigations of the Massachusetts Board of Health which were carried on a few years ago, it was found that if given quantities of sewage were discharged through open beds of gravel at regular intervals, as many bacteria were found in the filtrate at the first discharge as in the waste matter discharged into the gravel bed. After the gravel bed had been in use some time, however, with the proper intervals between discharges, it was found that the filtrate running away from the gravel beds was free from a harmful percentage of bacteria. Upon investigation this was explained in the following manner: When the sewerage was first discharged through the gravel, the gravel was clean and no forms of life that are at war with the bacteria were present. During the intervals, the food for the warring elements being present, their seed became planted there and grew, thriving upon the bacteria and other material furnished by the discharges.

Now this applies directly to the water supply of all large cities where filter beds are used. Take a freshly made filter bed and the water comes through impure. After a little time algoid vegetation—the green slime—begins to grow at the bottom of the water and on the sides of the filter beds. As this accumulates the bacteria are retarded in the meshes of this fine vegetation, which in some way destroys the bacteria. Finally the meshes become so fine that even the water does not percolate. Then the bed must be cleaned, but no new filter bed, nor freshly cleaned one, should be used to supply a city with drinking water.

In the city of Berlin, some years since, a portion of the city supplied with a certain filter bed became short of water. The level of the water was raised two feet in this bed, to give a greater pressure and force more water through the filter. The result was an immediate outbreak of typhoid fever in the part of the city supplied by this particular filter bed, and in no other part of the city. The most plausible explanation is, of course, that these bacteria had been accumulated in large quantities in the meshes of the vegetation growing on the surface of the filter, and that the sudden heavy pressure had forced them through the filter before there had been time for them to meet their death at the hands of their natural enemies.

The new water-works of Berlin furnish us a lesson in the scientific way in which the question is handled. Beside the usual corps of engineers, they have two bacteriological laboratories located at two different points of supply. Dr. Proskauer, who has charge of these laboratories, was the first one to show that it was not the sand alone, but the algoid vegetation on its surface that formed the filter arresting the bacteria and in some way absorbing or removing the dissolved organic matter. After the beds have been cleaned the filtrate for the first forty-eight hours is rejected. There are in this system twenty-two filter beds, of which only sixteen are in use at one time, while the remainder are being cleansed. To avoid all possible cause of error from any flaw in the filter bed, the filtrate is examined daily in the bacteriological laboratories. Koch's three rules regarding filtration are rigidly enforced. These are:

(1) That the rate of filtration shall never exceed 100 mm. per hour.

(2) That the filtrate of each basin shall be examined daily while in use.

(3) That the filtered water containing more than 100 bacteria to the c.cm. shall be rejected or pumped back into the unfiltered reservoir.

The average number in the water as now supplied to Berlin seldom amounts to 50 bacteria to the c.cm. The unfiltered Tegel water averages about 200, while the former source of supply in Spree contained

from 10,000 to 100,000 or more to the c.cm. A filter conducted on these principles should reduce the bacteria in a water that is badly contaminated, in the ratio of 1,000 to 1.

So far sewage has only been considered in the way it may affect our water supply. Now, consider it by itself. In what forms do we find it, and how may the disease-producing elements which it may contain reach us? We find sewage in leeching cesspools, in earth-closets, in tight cesspools, and in the city sewers. The leeching cesspool stands in exactly the same relation to surrounding wells that the sewerage discharged into a river does to the purity of the river. If we have a small enough supply of sewage and a great enough distance, we are safe. The earth-closet, when supplied with the proper kind of earth, is a sanitary appliance. The proper kind of earth is a dry loam, or surface garden soil dried without heat, which contains the forms of life that combat the noxious bacteria.

Before taking up the other forms of sewerage disposal, let us discuss the manner in which this sewerage can be harmful to ourselves. How do the disease-producing bacteria, that may be contained in the sewage, reach us? Are they carried through the air if the sewage is exposed? This is impossible unless the sewage is first dried, desiccated, and then exposed to the winds. As long as it is moist it is harmless to the air we breathe. Tests of the air in some large city sewers show a greater purity than the average well ventilated schoolroom when full of students. These organisms can only be carried to us by contact. The organisms that make the odors are not the disease-producing ones. The odoriferous bacteria are probably intended to keep us away from the foul matter in which they live. They are danger signals. They say "Don't touch." That great bug-bear—sewer-gas—is a harmless old fellow. He never hurt anybody any more than any other gas might do by reducing the amount of oxygen. It would be difficult to get a leak of sewer gas into a room from a well ventilated system of plumbing, that would vitiate the atmosphere anything like the amount that it is vitiated by an ordinary gas burner which uses, during a given period, at the least as much oxygen as eight persons. The elaborate system of back ventilation which is required of the plumbers by the health laws of most of our cities is a good thing to keep the plumbers busy, but all that it accomplishes otherwise is to keep an occasional whiff of air in a ventilated waste pipe from entering an apartment at the moment that a trap is siphoned.

Dr. A. C. Abbott, of the Laboratory of Hygiene of the University of Pennsylvania, during the winter of 1894–95 conducted some experiments upon animals, as to the nature of sewer gas and of the gases arising from decomposing organic material. He took some rats,

rabbits, and other animals, and placed them in glass jars. Over some he passed a continuous stream of sewer gas; over others, gases from decomposing material. This was continued without interruption for five or six weeks, and none of the animals suffered a loss of appetite, nor seemed otherwise any the worse for wear. And these are the animals which are especially subject to disease in laboratory experiment. To make the reason for this clearer, the statement that the disease-forming organisms are not gas producers may need a little explanation. The bacteria of decomposition almost universally produce gases. The parasitic bacteria seldom produce gas. They live on our bodies and in the passages and chambers of our bodies that communicate with the external air. We have a variety which lives in our intestines, that is a gas producer and which, if introduced into other portions of the body where bacteria do not normally belong, may produce disease. But, of the parasitic bacteria, a few are normally disease producers, and of these normal disease producers I do not know of one that produces gas. Even if they did the gas would not of necessity be poisonous.

What is wanted of a sewerage system is to take away the noxious material as rapidly as possible.

Returning for a moment to the different forms of sewage disposal, we find the tight cesspool harmless because the sewage in it is moist. It gives off plenty of gas however, which is inhaled by every visitor to the apartment above. City sewers, if well ventilated, tight, and well graded, are all that can be desired—but where are sewers to empty? This is the most difficult question to solve in this direction at present. A city like Buffalo, which has a river at its doors with a current of eight miles an hour, into which it can empty its sewage, and Lake Erie from which to draw its water supply, can easily solve the problem. A small town can use the irrigation and sewage farm method. Where land is cheap the farm products will nearly pay the expense of running. This system depends for its success on the bacteria of decomposition, and other vegetation. The experiments of the Massachusetts Board of Health, already referred to, explain the principles of this system. The works at Freehold, N. J., are a good illustration of this type. The city sewers discharge into a large tank or basin. When this basin is full the contained sewage is allowed to flow with full head through one of the distributing systems. There are, if I remember rightly, six different fields used in alternation. The discharged sewage, before flowing onto the fields, first flows through a barrier of broken stone, where the algoid vegetation does its destructive work. The alternation of the fields gives this vegetation time to develop—being swamped with food—and the several days' exposure to the sunlight between the floodings destroys the noxious bacteria that may have escaped the barriers of broken stone.

The solution of the problem in this city has been in the past merely a stern chase, moving the source of supply farther out into the lake, while the growth of the city is forcing larger supplies of sewage farther out into the lake. Taking the system just as it is, however, a daily bacteriological examination of the water at the intake would show whether the water was fit for drinking purposes, and the Water Works Department could keep the people of this city informed on this point.

Before closing, I should like to say a word about house filters. The old charcoal, or a sand filter, might do if they were only used one day in four or five, and exposed to air and light during the intermediate days. The wire filters that screw on the faucet and reverse are an abomination ; the retained bacteria have time to multiply, and are then slowly set free when the filter is reversed, and, after a time, the water passing through in either direction will contain more bacteria than is contained in the same amount of water in the pipe supplying the filter. I have noticed a pressure filter which contains a film of paper pulp to be removed daily. I should think that these might be very effective, although I have never seen a report of the condition of the filtrate from such a filter. Then we come to the earthenware filters. These answer their purpose if—and the if is a large one—if they are sterilized by heat about once in four days. It has been shown by experiment that after this period there is more bacteria contained in the filtrate than in the water that enters the filter. The explanation is that it takes about four days for the bacteria to grow through the pores of the earthenware, and after this is accomplished these earthenware walls become a breeding-place. If, however, one removes the earthenware portion and either lays it on the coals till raised to a red heat, or puts it in a steam chamber for half an hour, and repeats this operation every fourth day, the filter will then be perfectly safe. It is much better, however, to have the city furnish water that is perfectly safe for everyone to drink.

THE TESTING OF COALS.

By Arthur Winslow, Member of the Engineers' Club of St. Louis.

[Read before the Club, March 18, 1896.*]

The importance of a determination of the properties and relative values of different coals is so patent that no argument or illustration is needed in support. The problem has been under investigation for many years and has been attacked in various ways. There has been a development in the methods employed, and a clearer understanding has been reached of the results desired and of what it is practicable to attain. But much remains yet to be done.

With the long continued and abundant use which some coals have enjoyed, their individual values and adaptabilities for certain purposes have been pretty well established in practice. There are many other coals, however, concerning which this is not the case. Further, with most coals the questions of relative values for all uses and under all conditions are in a very unsettled state. The conditions of actual use are not sufficiently uniform, nor have the results been recorded with the exactness necessary for close comparisons. There is need of supplementary tests. It is true that there are few coals of which analyses have not been made. Calorimeter and boiler tests of many have been recorded. But, unfortunately, the results are generally not comparable or are incomplete. Some of the samples tested were of picked specimens; some represented sections of the coal bed; some were averages of car-load or other lots; some have been tested fresh from the mine; others after long exposure. The apparatus and methods used in different tests have been different, and not always those best adapted to the special coal. Some tests have been conducted by reliable men, others not. Therefore, a series of examinations and tests which will furnish information and results of uniform reliability and closely comparable, is still a desideratum; such a work will be of great value to all producers and consumers of coal.

This paper is the outcome of a plan of the writer's to conduct a study of North American coals along these lines. The work is already begun, but the plans and methods are not entirely matured. One object in presenting the matter at this stage is to lay these plans, so far as formulated, before you for discussion and suggestion. It was originally the writer's hope to be able to incorporate some results in illustration,

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but unavoidable delays in the prosecution of the work have prevented this, and have made the presentation perhaps a little premature. It is planned, however, to present some of the results in later communications.

The problem which first presents itself is the devising of a ready and practical method of determining the properties of coal with reference to actual uses. Such determination will establish directly the relative values of coals, and will reveal their special adaptabilities. The solving of this problem involves a consideration of the principal uses to which coals are put, and of the requirements of such uses. These may be included under the following five general heads, arranged about in the order of their importance:

(1) Steaming.
(2) Coke making.
(3) Domestic use.
(4) Gas making.
(5) Forge use or blacksmithing.

For steaming purposes the requirements vary according to the character of the furnace and boiler and the draught employed; they vary according to the use to which the boiler is put. In general, high evaporative power is desired in the coal, but in some cases quick steaming qualities are of more importance than heating value. High ash and moisture percentages, and the presence of harmful impurities, such as iron and sulphur compounds, are always objectionable, as is also a coal which makes a hard clinker, or much clinker or cinder of any kind. A too fusible and strongly caking coal cannot be regarded as best for steaming; yet, on the other hand, one which will not fuse or cinder at all, and is at the same time soft and friable, is liable to be wasted through the grate bars and up the stack. A good steaming coal should not make much soot, as this clogs the pipes and reduces the amount of steam made. It should reach consumers in a good condition, and to stand storage it must not slack much in handling or hauling, or by exposure to the weather. The results of test and practice lead to the conclusion that, up to a certain point, the coals high in fixed carbon have the greatest evaporative powers in the common types of furnaces and boilers; this quality, combined with the readiness of ignition and the free and complete burning of semi-anthracite and semi-bituminous coals, make them the steaming coals par excellence. They also produce little smoke and soot, which are important considerations in many uses.

The essential of a coking coal is that it coke. This some coals will not do. The second important consideration is the quality of the coke. Very inferior cokes find sale for domestic and some other uses, but they command a low price and their sale is limited. They can generally only

be made on a slack basis. Cokes which are of first grade for some uses occupy a second place for others. For iron smelting a very strong coke is necessary, one of moderate ash and very low in sulphur and phosphorus; for foundry use a coke of similar composition is required, but equal strength is not necessary. For lead smelting, and for treatment of ores of the precious metals, neither so strong nor so pure a coke is essential; the percentages of sulphur and phosphorus do not cut such a figure here; a moderate amount of ash is, of course, desirable, but this is qualified by the composition of the latter. In the manufacture of water-gas low sulphur is important in a coke. The density of a coke and the porosity are physical characteristics of some importance in metallurgical use. The amount of coal required to make a ton of coke, and the length of burning necessary, enter into the question. The lustre and fracture of the product affect its salability in the market.

For domestic use various kinds of coals are used, according as to whether they are to be burned in furnaces, ranges, self-heating base-burners or open grates. Dirty, impure and freely slacking coals are always objectionable, but small amounts of impurities are not of the importance here that they are with coals for metallurgical use. For large house furnaces good anthracites are undoubtedly the best. For ranges and base-burners anthracites are also good, but dry, semi-anthracites are sometimes preferred on account of their greater ease of ignition; a smoky, caking or intumescing bituminous coal is not adapted to such uses. In open grates almost all good coals are burned, the choice being very largely a matter of taste. A clinkering coal or one high in sulphur is bad in domestic as in steaming uses, but a coal which makes a clinker with the temperature of a boiler furnace may not do so with the lower temperature of domestic fires.

For gas-making the essentials are a large quantity of volatile hydrocarbons of good illuminating power. Sulphur in combination with iron, as iron pyrite, is the principal harmful impurity, and it has to be removed with lime or sponge. A large amount of ash is injurious in that it reduces the yield of gas per ton of coal and impairs the quality of the coke. The coking qualities of the coal also affect its value for gas use.

A forge or blacksmithing coal should be a moderately caking coal, containing very little sulphur and low in ash. Too fusible and pasty a coal is objectionable.

To find the value of a coal for these uses requires, therefore, the determination of certain facts of composition, of physical character, and of behavior in burning. To satisfy these demands the following scheme of work has been planned:

(1) An inspection of the coal at the mine.

(2) A personal collection of samples at the mines.

(3) A proximate analysis.

(4) A fuel test by calorimeter.

(5) A laboratory test of the coking and gas-producing qualities.

(6) A study of the best methods of burning, of the steaming value, of the durability in transportation and storage, and of the special adaptabilities as revealed in actual use.

Ultimate analyses, boiler tests, coke-oven tests, gas analyses, etc., will be made in addition only in special cases.

The experimental part of this work consists essentially of sample tests; but these are supplemented by observations upon and inquiry into the behavior in actual use. At the same time results of commercial tests heretofore made, and all other data obtainable, are industriously gathered. It would, of course, be preferable, and the scheme would be ideally perfect, could working tests be made for all the different uses of coal; but with a private undertaking it is manifestly impracticable to conduct tests of a great number of coals on such a scale and in such variety as to reproduce all conditions of practice, and it is recognizedly impossible to attain these conditions with tests of small samples. Hence, this compromise or combination of direct experiment and of observations on practice was decided upon as the most feasible plan of work, the results in the one line acting as guides and as supplements to those in the other.

Considering the plan of work in detail, the inspection of the coal at the mine and the personal collecting of the sample are considered of first importance. They not only enable one to vouch for the character of the sample, but they permit the necessary observations for securing a proper sample. At the same time valuable information can be gathered at the mine bearing upon the uses and behavior of the coal. The sample desired is one which will fairly represent the product of the coal bed at the special locality, as it can be shipped after proper preparation for the market. The coal shipped from any bed may vary according to local conditions and according to the care exercised at the mine in preparing it for market. The variations of the bed are ascertained by underground inspection. A sample is then selected which will represent a fair average of the product. This is generally done by collecting a large number of lumps from market or mine cars and from different benches of coal, and coming from different parts of the mine—between ten and twelve bushels in all. These are then broken down, well mixed, and successively quartered and broken until a sample consisting of about half a peck of small coal is left. In addition, about a peck of lumps of egg size are selected at random for special tests of hardness, burning, etc. These are shipped to headquarters at once and there the small sample is transferred to an

air-tight glass jar for future use and preservation. Such a sample is a fair average and is considered better, for other reasons, than one consisting of chippings from across the face of the bed in the mine.

The proximate analysis is the ordinary one, covering the determination of the fixed carbon, volatile hydrocarbons, moisture, ash and sulphur.

The fuel value test will be made in some form of oxygen calorimeter, which has recently received such strong endorsement for the determination of the qualities of coals by the committee on a "Standard Method of Conducting Locomotive Tests" of the American Society of Mechanical Engineers. The apparatus will probably be that devised by Mr. George H. Barrus, and described by him in Vol. XIV of the *Transactions of the American Society of Mechanical Engineers.* It is very simple in operation, and is free from the objectionable chemical reactions of the Thompson calorimeter. It appears to be capable of yielding amply accurate results for the purposes in view, and is cheaper and less complicated than the bomb calorimeters of Mahler and others. As stated, boiler tests are not contemplated excepting in special cases. Such are always as much a test of the boiler and furnace as of the coal, and it is not practicable to extend the tests of a coal to all the different types of boilers. Because a certain coal with one furnace yields a high or low result as compared with another coal, it does not follow that the same result will be obtained when different furnaces and boilers are used. Hence the usefulness of such tests in establishing the relative value of coals is not so great as might be imagined, and may even be misleading.

The tests of coking properties will be made in small fire clay crucibles. The results thus obtained may not be final in fixing the quality of the coke, but they will certainly establish the fact of coking or non-coking properties, and it is believed that careful observations and comparisons with results obtained from similar tests of standard coking coals will lead to much more.

The gas-making qualities will be inferred from the results of the analysis and from the behavior during the coking tests. Actual tests of the candle-power of the gas cannot ordinarily be attempted.

Tests of hardness, of igniting qualities, of fusibility or clinkering of ash, and other minor points, will be conducted so far as practicable, and these will all be checked by notes on and observations of the results reached in practice.

By these means it is believed that a series of facts and notes will be obtained, entirely comparable and subject to the same personal equation, which will be sufficient to establish the essential qualities of the different coals. These are, of course, always liable to local and temporary variations, according to the care of the miner, etc.; but such variations

are generally exhibited in the amounts of ash and sulphur, and in the proportions of slack and lump coal, which can be readily determined by simple inspection and proximate analysis, and can be corrected to the standard.

The results, though expressed in absolute terms, do not, of course, give absolute values. These are always relative to time and place. Without knowledge of these factors the money value of a coal can never be estimated. Many a hasty verdict has been passed and an enterprise obstructed by ignoring this fact. A coal which may be of very poor composition and of inferior qualities, to the extent that in some localities it would be practically worthless, may elsewhere, under different surroundings and market conditions, be a very merchantable product; and the reverse is equally true. This consideration, though somewhat aside from the subject of the paper, has a bearing upon the use of the results which we hope to attain.

METHODS AND RESULTS OF STADIA SURVEYING.

By F. B. Maltby, Member of the Engineers' Club of St. Louis.

[Read before the Club, June 3, 1896.*]

The theoretical and mathematical discussions of the method of measuring distances by the use of the stadia have been quite full, both in text-books and papers and discussions before this and other engineering societies. Without in any way wishing to cast disparagement on these theoretical discussions, the author has thought that some notes on the practical use of the stadia as gained principally from his own practice covering a number of years may be of interest.

Your attention is first called to methods employed, afterward to some examples of results attained. First to be considered under the head of methods are the appliances used. The old adage to the effect that "any one can do good work with good tools," but that it takes a mechanic to produce good work with poor tools, may be true of some kinds of work, but the author does not think that even a mechanic or a trained observer can do first-class topographical work with poor instruments.

The first of the appliances is the transit or theodolite, and I wish to urge very strongly, at the start, the importance and necessity of a first-class instrument. By this I mean not only one of good mechanical workmanship, but one designed and adapted to this work. In the opinion of the writer, one of the principal reasons for the feeling of distrust, held by some engineers, of work done by the stadia method is derived from the unsatisfactory results obtained by the use of instruments unsuited to the purpose.

An instrument should possess the following qualities: It should be thoroughly rigid, and heavy enough to provide stability in a strong wind. The graduations should be accurate, deeply cut and clear, and the horizontal circle marked to read from left to right, from 0° to 360°, and should read by vernier to 20″ at most. The telescope (the important part for long range and accurate reading) should be powerful, magnifying not less than 30 diameters, and the field should be perfectly flat and as large as possible. To meet these conditions means a very much larger object-glass and longer barrel than ordinarily used on engineers' transits. To save light absorbed by an extra lense it should preferably have an inverting eye-piece. The instrument should have a vertical circle divided and reading by vernier to the same divisions as

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those on the horizontal circle, to avoid confusion in reading. The vernier should swing from the horizontal axis of the telescope and be provided with a tangent screw for moving it independently of the rest of the instrument. It should be provided with a level tube so adjusted that when the line of collimation is horizontal, and the vertical circle reads zero, the bubble will stand in the center. This arrangement will enable one to read vertical angles accurately, regardless of the fact that the plates of the instrument may not be exactly horizontal, and it is strictly essential where elevations are to be determined with a reasonable degree of accuracy with vertical angles.

The highest grades of instruments ordinarily made in this country for railroad and municipal work do not meet all the above requirements. In consequence, where the work in hand is extensive enough to warrant the expense, it is desirable to have an instrument made for the purpose.

For use on the topographical survey of the City of St. Louis, Mr. B. H. Colby had two made, one by Fauth and one by Buff & Berger. The writer, for use on work of such an extent as to prohibit the cost of an instrument made to order, has had a vernier level attached to a high-grade Buff & Berger transit, and it has given excellent satisfaction, the only fault being that the telescope is hardly strong enough. The Mississippi River Commission have recently had made two theodolites especially designed for this work. By courtesy of Mr. J. A. Ockerson, under whose direction they were designed and made, I am able to give the specifications of this instrument. In the writer's opinion this is the model topographical instrument.

The matter of rods and their marking has been much discussed. Only recently this club listened to a paper on the subject. It is found, all things considered, that a clear, well seasoned white pine board, 5 inches wide, 12 to 14 feet long, and about $\frac{5}{8}$ inch thick, gives the best satisfaction. A jointed or hinged rod has been advocated, but a joint that is rigid and will stand the rough usage to which a rod is put must be very cumbersome and heavy, and, in the writer's opinion, the small matter of slightly more portability is hardly worth what it costs. The rod should be lightly shod with strap iron at each end to prevent splitting and wearing off of corners. A small hole drilled in the center of the shoe, and the use of a headless nail driven in the top of the stake will enable a rodman to always hold the rod on the exact point marking the station. It is also quite a help to a rodman in holding his rod plumb in a high wind—a small detail but a convenient one. The rod should be given two or three heavy coats of white paint. The figures should be black, with the larger units painted red, for ease in "counting up." The marking should be symmetrical with the center of the board, in order that either end may be held up.

The shape of the figure to be used is largely a matter of individual preference. I suppose that nearly every one who has used the stadia extensively has designed, tried and usually discarded at least one figure. In looking over the available literature on this subject I have been somewhat amused to note the great variety of figures and ways of mark-

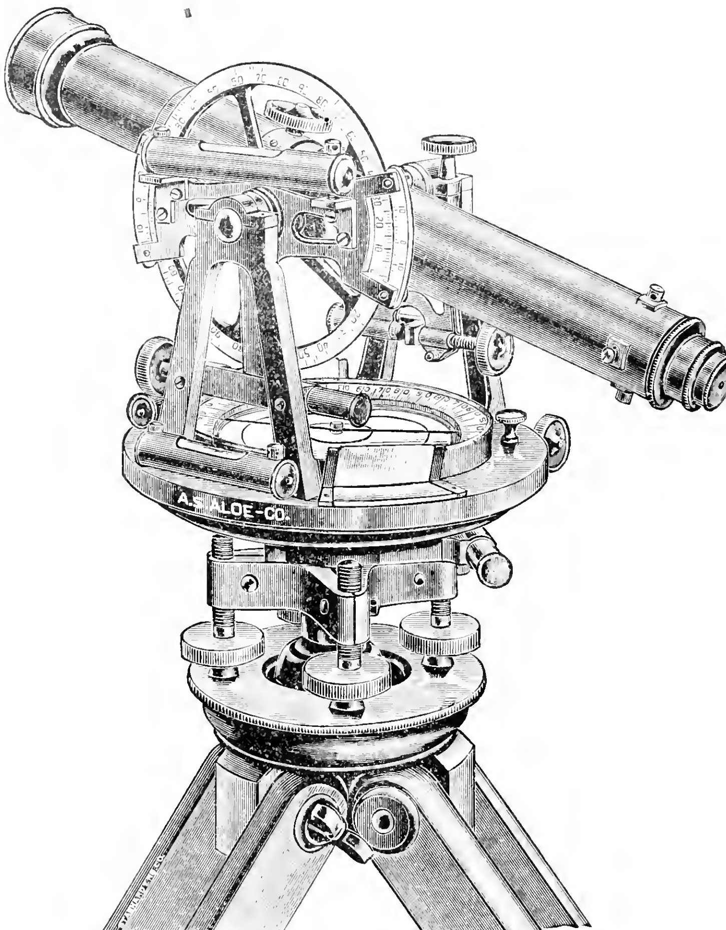


Fig. 1.

Topographical Theodolite made for Mississippi River Commission, 1895.

ing a rod that have been advanced. Many of them have many meritorious features under certain conditions. It is, however, desirable to keep the colors together, as much as possible, by using large figures which will largely prevent their running together when the air is unsteady. It is better to use large figures and subdivide them by means

of angles and points, than to use a multiplicity of figures. The writer has never used a figure that as fully answers all the requirements as that adopted on the survey of the Great Lakes, and commonly known as the "Lake survey figure," and universally used on the topographical surveys made by the Mississippi and Missouri River Commissions, and also on the topographical surveys of St. Louis and Baltimore.

The general practice of marking rods on work with which the writer has been connected has been to measure a base of such length as is estimated will be the average distance between stadia stakes, measure the interval subtended a number of times, take the average and subdivide the rod proportionally. Or, better yet, measure a number of distances covering a range likely to be used in practice, determine the interval for each distance, take the mean of all and subdivide the rod proportionally. This method has one advantage, and that one is of considerable importance, that is, distances are read directly from the rod and can be platted as read without further reduction being required. Where the work is to be platted on a scale of 1 in 5,000, or smaller, and where, as in contour work, the vast majority of the side shots are for elevation only, and their exact position not essential, and as the rods can readily be graduated to read with an error not to exceed 1 in 600 to 800 or closer, the error of location is well within the limits of ordinary platting. As the side shots comprise 90 per cent. of the readings taken, the advantage of the ability to plat them without any reduction, and on work of wide extent, is readily appreciated. Of course it is understood that the rod reading is correct only for the distance for which it was graduated. Another disadvantage is that the interval is not always determined under the same conditions actually met with in use of the rods.

For work on a large scale, say 100 to 400 feet per inch, and where a large amount of accurate detail is to be determined, it is possible that the method advocated by Mr. J. L. Van Ornum in his paper on the Topography of the Survey of the U. S. Mexican Boundary, in *Trans. Am. Soc. C. E.*, is the best.

This method is to subdivide the rods into standard units, uch as feet, yards, meters, etc., and to determine the rod interval and use a conversion table for reducing rod readings to distances. It has the advantage, among others mentioned by Mr. Van Ornum, of being able to keep standard rods in stock and ready for use, and that the interval can be determined under all conditions of practice. Instead of a small number of readings over a picked base, the interval can be determined by running between known points and observing under all the conditions of sunshine and shade, and all kinds of temperature and state of humidity; in other words, a constant determination of the interval whenever prac-

ticable. And in case it changes, as it does, it is only necessary to change or correct the tables instead of repainting the rods. The disadvantage, as before stated, lies in the necessity for converting all rod readings to distances, a process taking some time.

The wire interval to be used is quite important. The smaller the angle subtended by the cross wires the longer will be the distance at which a rod of given length can be read, and the wider the angle the greater the degree of precision with which the divisions on the rod can be read and subdivided. The choice of the angle depends somewhat on the scale to be used and the amount of detail and accuracy required. The choice of a large or a small angle is also practically limited to a rather small range, and it should depend on and be consistent with the power of the instrument. If the angle is too small, the figures on the rod will be so small that they cannot be distinguished at a long distance, or if a rod divided into standard units is used, the error in reading the interval affects the determination of the distance to a greater proportion. Thus if the interval is 1 in 100 then an error in reading the interval .01 foot makes an error in the determination of the distance of one foot. If the interval be .5 to 100, or 1 in 200, then the same error in reading the interval makes an error of 2 feet in the determination of the distance. If the angle is too large, there is trouble in taking in both wires at the same glance, and second, unless the telescope has a perfectly flat field, it is difficult to bring all the wires into the same focus.

In the ordinary American transit the angle subtended by the cross wires is about 34 minutes, or the space subtended on the rod is $\frac{1}{100}$ of the horizontal distance from the telescope. With the instruments in use on the surveys of the Mississippi River the most satisfactory interval has been found to be about .8 foot per 100 feet. On the Missouri River .8 to 1.0 per 100 are used; on the Baltimore survey 1 foot and 1.5 per 100 foot were used; and on the St. Louis topographical survey about .9 foot per 100. In this connection the standard unit for horizontal distance to be used, whether feet, yards or meters, is important as affecting the size of the spots, as it is quite essential that for speed and accuracy in counting up, the rod should be decimally divided, whatever the interval or whatever the unit of distance used. Now if an interval of 1 in 100 is used and horizontal distances are to be measured in feet, then to carry out the decimal system of subdividing the rod 10 feet on the ground is represented by 0.1 foot on the the rod, making a spot too small to be distinguished or subdivided except at short distances. On the U. S. Coast Survey, the survey of the Mississippi River, in St. Louis, Baltimore and other places, the meter is the unit of distances. Without entering into a discussion on the merits of the metric system, I will only say in this connection that one advantage of its use is that it is found

that the 10-meter spots are of the best size for the usual range of work. On work of a private nature, or for corporation, the yard possesses the same advantage as the meter in this respect, with the additional advantage of being more readily converted to the usual standard unit of feet.

Coming now to the field work, we have first to consider the organization of the field party. It should consist of an observer, a recorder (who should be a rapid writer, and one able to make neat and legible figures, and, preferably, one able to assist in reducing the notes), and such a number of rodmen as will keep the observer fully occupied. It is economy to have enough rodmen so that if there is any waiting to be done the low-priced men may wait on the observer rather than to have the high-priced observer waiting for the rodmen to get around. On work of considerable detail and large scale, where the rodmen have only short distances to walk between shots, two may be enough, while in open rolling country with little detail and where a small scale is used, four may be required. Where there is timber or brush there should be the necessary number of axmen.

A certain piece of work requires that a certain number of points be located; obviously the progress of the work depends on the speed with which the observer is able to locate these points. Now a good observer in open country and with the detail usually required on scales, say of 500 feet to an inch, or larger, can locate 500 points per day. There are men who can do more. Counting the time in getting to and from the field and the time lost in going from one stake to another, there will usually not be more than five and a half to six hours per day for actual observing, or say one and a half shots per minute, or forty seconds per shot, and as each shot means, first of all, directing the rodmen more or less, pointing the instrument, reading the distance, the azimuth and the vertical angle, it is self-evident that a man cannot do his own recording at this speed, and, in fact, it takes a rapid recorder to keep up with the observer. To attain this speed there must always be a rod up ready to be read, and as it only takes a wait of about twelve seconds between each shot to reduce the amount of work done 25 per cent., the economy of having all the rodmen required is apparent. I enlarge on this subject because there seems to be an impression that where only a limited amount of work is to be done, an observer who can record for himself and one or two rodmen are all that are necessary. Topographical work can be done in that way, but not economically.

The success in obtaining the required results, which are the objects in view in making the survey, depends almost entirely on the discretion and experience of the observer. It has been said that successful topographers are born, not made. This I believe to be true only in a limited sense, as I believe anyone with intelligence sufficient to grasp

the idea of what is required can become a topographer. Generally speaking, a topographical survey, for whatever purpose required, is made, as the name indicates, with the object of showing on paper the configuration of the surface of the ground covered. It may also, and if made on a large scale usually does, show artificial features and limits of culture. The successful observer will keep the former idea in mind and locate such points on the ground as are the controlling points in determining the features to be reproduced on the map. Shots taken indiscriminately not only take time in locating points not required, but may be misleading, inasmuch as they may not be controlling or limiting points.

The scale to be used on the map must also be borne in mind. It would manifestly be absurd for one to locate with the same detail features which are to be platted on a scale of 1 in 10,000 and 5-foot contour interval as those to be platted on a scale of 2 or 400 feet to the inch and contour intervals of 1 or 2 feet. Another desirable requisite is to cover the entire area to be surveyed with the same detail. These matters of the distribution of located points and the scale used are important. I have seen topographers, and not always new ones, who would locate points over a limited area with such detail that it was almost impossible to get them all on the paper, they were so close together, and then there may have been a space of a thousand feet or more in which no points were located.

Another matter in the distribution of located points to be observed, especially in gently rolling country, is that (if you will permit the expression) of running across the contours, that is, when the view from the instrument is obstructed by timber, weeds, brush, etc., let the lines to be cleared out be in a direction at right angles to the contours, or in open country let the paths gone over by the rodman in giving shots cut the contours at right angles. This may seem a small matter in detail, but on such small matters the successful map may depend, and the knowledge of the non-observance of this point by some topographers leads me to speak of it.

In the matter of sketching in the field, my experience leads me to take an entirely opposite view to that advanced by Mr. B. H. Colby in his very able paper on the topographical survey of St. Louis, presented before this club some time ago. Mr. Colby's idea is that sketching is entirely useless, and worse than useless, as it is a waste of time. He advances the idea that by the adoption of a proper nomenclature in keeping notes the controlling points may be positively identified and any sketch is useless. To this I must take exception. I cannot conceive of any system of notes being as plain to one entirely unacquainted with the ground surveyed as a well executed sketch. It has been said

that "a sketch is a universal language that is understood by any one, and requires no key or guide to its meaning." It is essential where others than those who did the field-work do the platting that the notes, or combination of notes and sketches, should be entirely clear and subject to but one interpretation. I do not advocate the indiscriminate sketching without scale in the pages of the note-books, as the value of the sketch then largely depends on the artistic ability of the observer to reproduce on the sketch his impression of the country before him, or the way it looks to him from his point of view. The result as obtained from the platted notes may be entirely different. A description of the system of sketching in use in the survey of the Mississippi and Missouri Rivers will embody my idea of what a sketch should be. This system was devised in the office of the Mississippi River Commission, and has

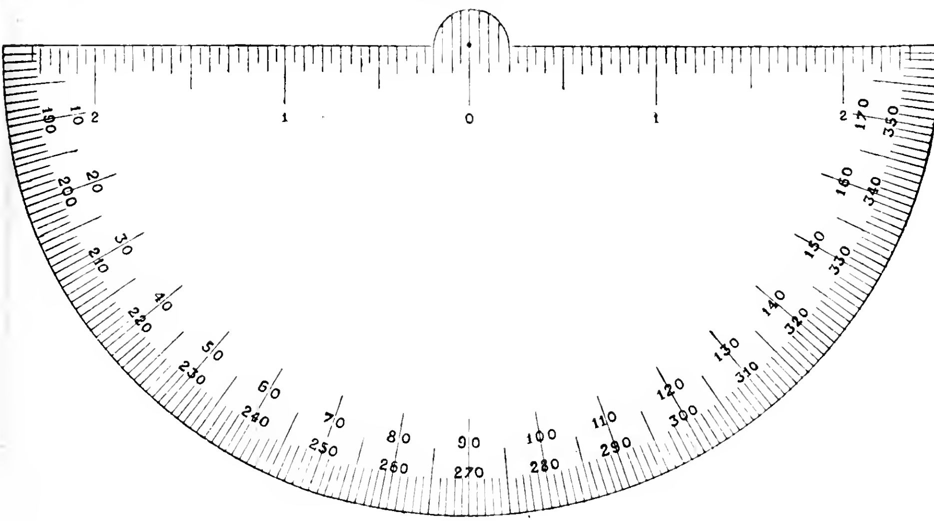


FIG. 2.

been adopted for their work and that done by the Missouri River Commission.

Sheets of paper are provided, 8 inches by 10 inches, ruled with light blue ink into squares, the lineal dimensions of which are some even division of the scale employed on the maps. A semi-circular celluloid or composition protractor (shown in Fig. 2) is used. It is 5 inches in diameter and is divided into degrees and numbered as shown. The edge along the diameter is divided into the scale to be used in platting (in this instance 10 parts to the inch, or a scale of 1000 feet to the inch) and numbered from the center each way. At the center there is a projection through which is a small hole at the exact center of the protractor. This hole is

also the zero of the scale. A pin fastens it to the paper and board. A very light drawing-board, about 15 inches by 20 inches, and a few thumb tacks complete the outfit. The method of using is as follows:

After having observed at the first station or stadia stake, the observer selects a point on the sheet as a starting-point to represent the station just observed from, and with the pin through the protractor at this point and using the ruled lines as north and south lines from which azimuth is platted, and using the scale on the edge of the protractor for distance plats the points located and also the next instrument station. These platted points are suitably joined and such information as is required is written on the sketch. At the next station the position already platted is used and the points located from it are treated in the same way, and thus the sketch grows as the work proceeds. When the edge of the sheet is reached another one is pinned down lapping over it a little, and the platting proceeds and may cover any number of sheets, the first being taken up from the board to make room for additional ones. The sheets are numbered and properly marked at their joining edges so that they may be readily placed together again in their proper position. Elevations are not platted and abrupt changes in elevation are indicated by hachures or approximate contour lines. No attempt is made to make a finished or artistic drawing, but the information required is placed on them in the quickest and clearest way possible. Not all the points located are platted, but only those sufficient for controlling points. Neither is it expected that the platting will be as accurately done as it will be done on the maps, but sufficiently so to show the relative position of located points and the proper way of joining them.

This method of sketching gives to the stadia method with transit the advantages claimed by the advocates of the use of the plane table, that is, the sketching or filling in is done by the observer on the ground, and with the features to be represented before him. It is without the disadvantage of the cumbersome board, tripod, allidade, etc., etc., of the plane table. There is a further advantage in this method that work can be done in any kind of weather that instrumental work of any kind should be done in, while with the plane table and large sheets, which are also sometimes used as the finished sheets, work cannot be done in damp weather or in a high wind.

Another advantage in sketching or platting the work as it proceeds is that it always shows to the observer what ground has been covered, and points out in what direction to proceed to cover the remaining ground to be surveyed. This is especially desirable in work of considerable extent and with an observer lacking in the quality known as "location."

The extra time required, if any, is very small; usually the observer

can do the platting and sketching while the recorder is going forward and setting up over the next stake. With this method nothing is left to the memory of the observer. On extended surveys such as those undertaken by the Government, or of areas of considerable extent for corporations, and where possibly the field party is subsisted in camp and the facilities for mapping are limited, all the energies of the party can be directed toward field work, with no delay caused by keeping notes platted and with the consciousness that everything surveyed is a matter of record, and will not be forgotten or confused. On completion of the field work, the remainder of the field party can be discharged and the observer can repair to an office where facilities may be had, and the

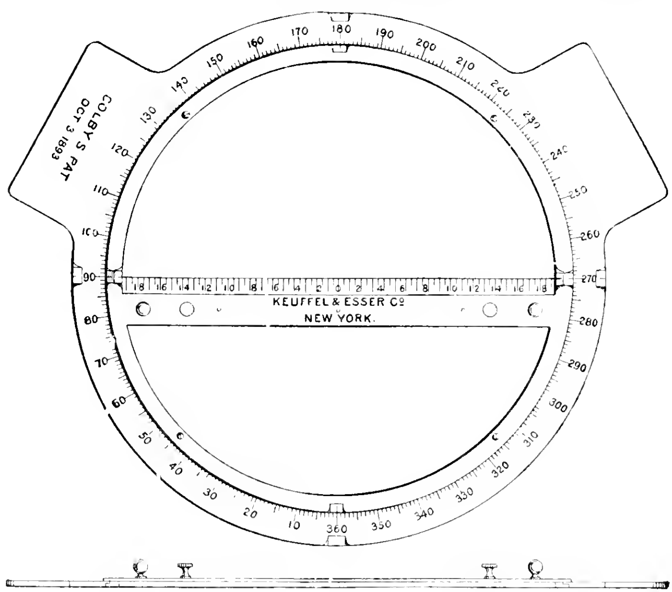


FIG. 3.
THE COLBY SLIDE-RULE.

map worked up at his convenience, or notes and sketches can be sent in and worked up equally well by one who has never been over the ground. Mr. Colby cites a railroad yard, with its complications of sidings, switches, cross-overs, etc., as being a test of the utility of his method. I can hardly imagine any system of notes that would make the different features of such a yard as clear to one who had never seen it as a well-executed sketch as I have described.

For reducing and platting the notes, suitable appliances are as essential as the field instruments. Differences of elevation being determined by vertical angles, it is necessary to reduce them to differences in feet

and tenths, or such units as may be used. For this purpose, numerous tables and diagrams have been devised. The most extensive and best arranged tables, so far as my own knowledge extends, are those prepared by Mr. J. A. Ockerson and Mr. Jared Teeple. They are quite complete, covering all angles and distances met with in ordinary practice. They are to be used where the distances are read in meters and differences in feet desired. Where other units are to be used, a reduction would be necessary.

So far as I have seen, the most successful device for obtaining these differences is the Colby slide-rule, a device described in Mr. Colby's paper, before referred to. With the use of this rule, horizontal distances may be read in feet, meters or yards, or any other unit, and the differences obtained in feet or the same unit as is used for horizontal measurements. As speed is one of the essentials of these reductions, I may say that I recently kept a record of the amount of work done with this rule by one man, in the office of the Missouri River Commission, and without his knowledge. During 54 working hours, he reduced 192 differences per hour, or a little over 3 per minute. Working under pressure, or for a record, one could exceed this rate considerably.

In platting the notes, the stakes are platted either by the use of rectangular co-ordinates or by polar co-ordinates, using a protractor printed on the sheet, and a parallel ruler for direction and a diagonal scale for distance. The advantages of the first method are that specially prepared protractor-sheets are not required. The co-ordinates are worked out and adjusted before platting, and any error in platting affects only one stake. Also in checking on the known position of well-located points, the error of closure is that of the field-work alone, and does not include errors of platting. The disadvantage lies in the time required.

The second method has a considerable advantage in the time required, and with suitable appliances can be made very accurate. The disadvantages are the necessity of specially prepared protractor-sheets, the fact that an error in platting one course affects all subsequent stakes depending on it for position, and also the disadvantage in closing on known points of deciding how much of the error is due to platting and how much to field-work.

During the past summer I had 295 circuits platted by polar co-ordinates for temporary use. Afterwards, the co-ordinates of the same stakes were computed. The average closure obtained by platting was 1 in 764. Average closure of same work by computation is 1 in 1228. These average figures do not show a true comparison, as in many cases the closure differed very widely and sometimes with the opposite sign.

For plating side-shots, some form of protractor is used. Two very good ones have been devised, and each has been used by the writer with

considerable satisfaction. One, by Mr. J. A. Ockerson, is made and sold by A. S. Aloe & Co., and fully described in their catalogue, and one by Mr. B. H. Colby, described in his paper before mentioned, and is made and sold by Keuffel & Esser Co.

The first is fastened to and swings on a pin-point through the platted position of the stake on the paper. Where the platting is done directly on what becomes the finished map, the objection of marring the paper in this way is quite a serious one. If the work is first platted on protractor-sheets, and then transferred to the detail-charts, this objection disappears. It has also the advantage of costing only about one-third as much as the other one.

The second one has the advantage that it is self-contained, and is held in place on the paper by weights, and does not mar the paper. The moving part is slightly raised, and does not soil the paper in moving it back and forth. As to the amount of work that can be done with them, a count was recently made of the work done by two men using the Colby protractor (one calling off and one platting) in 25½ hours, and the result shows 216 shots per hour, or 3.6 per minute. About the same speed can be made with the other one mentioned, and this speed considerably exceeded under pressure.

The real test of the accuracy of stadia work is the map itself, and the truth with which it represents the features of the ground covered by the survey. It is said of the engineer officer in charge of the survey of the Great Lakes, that it was his custom to take a chart to the ground which it represented, and picking out three or more well-defined points which were in line, would insist that a line drawn with a straight edge should pass through the same points as represented on the map. This would be a very rigid test, and one that, under ordinary conditions, could not be applied.

The usual way of stating the degree of accuracy attained by stadia work is to give the ratio of the amount of error in closing on a point of known position to the distance as measured through various courses from a preceding known point. This degree of accuracy will vary widely, as will the degree of accuracy obtained in chaining vary widely, when done by different men, for different purposes, and under different conditions. The usual way of stating the error of work where a number of checks have been made is to give the algebraic sum of all closures, and as the signs of errors vary, they tend to balance each other, and the result may show a proportion running into large figures, while individual errors may have been very large. While this method is fair enough if understood, it does not give a true idea of the actual accuracy of the work. The real value is a mean of all closures of short portions, and giving each equal weight.

From Mr. Colby's paper, I find the average closure as obtained over 24 courses between located points to be 1 in 667. The errors in this case are all in the same direction with regard to the direction of the lines, and I understand that since the paper was published, it has been found that the rod interval should have a correction of about 1 in 600 in the opposite direction. If this correction were made to the calculations, the errors would be very small. Mr. Van Ornum gives the average error of the work on the Mexican Boundary survey as 1 in 949. This work covers 182 miles of line, and is the average of 32 checks.

Mr. Jolly, Assistant Engineer, Sewer Department, gives me the following table of 17 checks on work done in St. Louis during 1895. The average is 1 in 2390. On one course the closure is abnormally high, being 1 in about 15,000. Leaving this course out, would give an average of 1 in 1540, which is probably nearer the true degree of accuracy.

TABLE OF ERRORS IN CLOSURE.

Topographical Survey of St. Louis.

By E. J. Jolly, Assistant Engineer Sewer Department, 1895.

No.	From	To	Number of Courses read.	Average Length of Course.	Total Distance.	Error.	Proportional Error.	Remarks.
				M.	M.	M.		
1	St. Cyr.	□ 4031	9	265	2383.6	0.90	1 : 2648	These courses are approximately in a straight line, and errors are due to distance almost entirely.
2	□ 4031	△ Robinson.	5	300	1501.5	0.98	1 : 1533	
3	□ 4032	□ 4036	3	298	893.1	0.72	1 : 1240	
4	□ 4036	Base Stone.	4	216	866.2	0.84	1 : 1031	
5	□ 4036	□ 4043	3	187	560.1	0.71	1 : 789	
6	□ 4044	City Limit, 174.	6	249	1493.4	1.73	1 : 863	
7	4038	□ 4033	5	237	1186.5	0.33	1 : 3595	
8	Conduit	St. Cyr.	14	310	4332.2	0.29	1 : 14938	
9	□ 3962	□ 2795	13	273	3549.6	3.28	1 : 1081	
10	3962	□ 4061	4	121	483 6	0.69	1 : 750	
11	4060	□ 4016	13	341	4437.4	2.45	1 : 1811	
12	4082	4094	4	281	1125.7	0.32	1 : 3474	
13	4075	□ 4084	5	185	925.8	0.96	1 : 960	
14	4086	□ 4085	3	215	646.4	0.69	1 : 941	
15	4085	□ 4095	5	234	1168 3	0.61	1 : 1918	
16	3967	3966	2	228	457.3	0.69	1 : 663	

The average error of work done on the Missouri River during field season of 1895, covering 220 miles of river and about 425 square miles of topography, is 1 in 1004. This average covers all checks, 636 in number, and includes circuits which start and close on stadia stakes, the position of which had been adjusted and may have been somewhat in error. The average closure of 116 lines run between triangulation stations is 1 in 1390. The average length of these lines is 7,109 feet.

The above average is the result of 1,650 miles of main stadia line measured by four observers.

All the above results are obtained by computing the co-ordinates of stakes, and represent errors of field work only. The above results are not given to invite comparison, as they are not comparable. They are results of work done under widely different conditions and for different purposes, and each represents a degree of accuracy which was probably all that was required or desired for the purposes for which the surveys were made. They are not given as examples of what can be or should be done with the stadia, but simply as a few instances of what has been done.

I have endeavored to obtain some records of the accuracy attained by chaining or measuring with steel tape, as is usually done over rough ground and through the brush and weeds ordinarily encountered, but as far as I have been able to find, information on this subject is extremely rare, and such records as I have found are those of work done with more than ordinary care. Mr. Van Ornum, in his paper referred to, gives the average error of five tests with chain as being 1 in 1436, and this after a correction of dropped chain lengths which were detected by the stadia, had been applied. Professor Baker, in *Engineering News*, October 3, 1895, gives a few instances of accuracy in chaining. He gives the average error on public land surveys as 1 in 500; discrepancy between preliminary and location surveys on At., T. & S. F. R. R. as 1 in 2500, also error in chaining by students as from 1 in 400 to 1 in 1000.

My own experience and that of others leads me to believe that with proper appliances an experienced observer with reasonable care can easily obtain an average accuracy of 1 in 1200 to 1500, which, though it may not be as accurate as chaining *can* be done, is, I believe, more accurate than ordinary chaining *is* done, and is certainly well within the limits of errors discoverable on maps of ordinary scales.

As to the degree of accuracy attained in carrying levels by the use of vertical angles, there seems to be very little information printed. My own experience has been that with a level attached to vernier arm of vertical circle, elevations can be carried with an error not exceeding .5 foot for all distances. The long distances showing less error as they tend to balance. A stadia line run last summer about 15 miles in

length and over which levels were run, checking on each stake, showed discrepancies between consecutive stakes of as high as 0.2 foot, the total error for the 15 miles was less than one foot. The average closure of 123 circuits run in 1895 by four observers using instruments without vernier levels, and depending on plate levels alone, was 0.52 foot, the average number of stakes or courses in each circuit is 7.8.

The cost of stadia surveys varies as widely as the number of surveys made. The topographical survey of Baltimore cost for topography alone, excluding triangulation and precise levels, about $1.50 per acre. The scale of the map of this survey is 200 feet per inch, and all buildings, streets, alleys, etc., are located.

The cost of the topography of the survey of St. Louis is given by Mr. Colby as 73 cents per acre; scale of map the same, but few buildings and few street corners were located. A topographical survey of about 3000 acres in the vicinity of Madison, Ill., made in the winter of 1893, by the writer, at a cost of 50 cents per acre, including mapping, scale was 400 feet to the inch, and all buildings, fences, railroads, etc., were located. Several different tracts of land in the vicinity of St. Louis, covering from 100 to 200 acres, have been surveyed at a cost of from 20 to 40 cents per acre. In these cases a scale of 400 feet per inch was used, and contour interval of 2 feet, and only the configuration of the ground determined. A survey of about 9300 acres was made by the writer in Southwest Texas, during the summer of 1894, and the map was made on scale of 400 feet per inch, contours 2 feet apart. Ground was partly covered with brush, and was rolling, though not much broken. Circumstances were favorable for doing rapid work. The cost of completed map was a little less than 7 cents per acre.

Topographical work on the Mississippi River, in 1891, cost about $36.00 per square mile; on the Missouri River, in 1895, a little less than $31.00 per square mile, or from 5 to 5½ cents per acre. This work is platted on scale of about 1000 feet to the inch. Contour intervals are 5 feet, and all buildings, roads, fences, limits of culture, etc., are located. This cost does not include mapping except such field plats as are made in the field, but does include a system of tertiary triangulation on which the topography is based.

Nearly every writer that I have consulted on the subject of stadia surveying, has enlarged more or less on the advantage of the use of the stadia, and the adaptability and flexibility of this method of surveying, so that little remains for me to say in this respect. As the opinion of those who have used it extensively seems to be unanimous as to the desirability of its use, it is a constant wonder to me that it is not in use more extensively. For use in the preliminary work of locating, estimating and reporting on various proposed enterprises of improving land

for subdividing, drainage systems, railroads, canals, irrigation systems, etc., it offers a method of securing desirable and necessary information cheaply, accurately and rapidly, which cannot otherwise be obtained except by laborious and expensive methods.

Specifications for Topographical Theodolites made for Mississippi River Commission, 1895.

A good topographical instrument must possess the following points:

1. It must have an exceptionally good telescope for reading the stadia rod.

2. It must have a good vertical circle, with a delicate level attached to the vernier arm, for carrying levels by means of vertical angles.

3. It must have a good horizontal limb for carrying azimuth.

4. It must be so made as to admit of being easily and firmly clamped to the tripod, so it can be carried with safety.

5. The horizontal and vertical circles should read the same and should be divided into the same number of divisions.

These are the most important features, mentioned in about the order of their value.

1. *General Style of Instrument.*—The general style of instrument as regards plates, compass box, foot-screws, shifting head, etc., should be similar to the Buff & Berger transits of latest patterns.

2. *The Limb.*—This should be 6 inches in diameter and should be divided on solid silver into twenty minute spaces. The divisions should be numbered from 0 to 360 degrees, with figures at each 10 degree division, the numbers increasing to the right, similar to a watch-dial (see Fig. II, Keuffel & Esser Catalogue, page 284). The marks should be deep, full, smooth and distinct and the whole lacquered so that the limb will not tarnish. The limb should be entirely covered and have suitable glass plates through which to read the verniers, substantially as used in the Buff & Berger instruments. The clamp and slow-motion screw will be of same style as Keuffel & Esser's latest patterns.

3. *The Verniers* should be set at points 45 degrees from the line of sight, to the left of the eye-piece and right of objective, and the vernier nearest the eye-piece should be marked A and the other one B. The verniers should be divided in such a way that 39 parts on the limb will equal 40 parts on the vernier, and read to half minutes. The zero should be at the right-hand end and the five minute divisions should be numbered to the left. Each vernier will be provided with a ground glass reflector suitably placed. The graduation marks should be deep, full, smooth and distinct.

4. *The Compass.*—The compass circle will be divided to one-half degrees and the graduations will be numbered from 0 to 360 degrees and

from right to left, or the opposite direction of that of the limb. The circle should be large enough to permit the use of a $4\frac{1}{4}$ inch needle. This needle, its mountings and bearings, will be of the very best quality. It will be provided with suitable lift for raising needle free from pivot. The compass box will be provided with suitable glass.

5. *The Levels on Vernier Plates.*—The vernier plate will be provided with two levels placed at right angles to each other, one at foot and outside of telescope standards, parallel to telescope and one parallel to axis of telescope under objective end of telescope. These levels will be about 3 inches long and ground to a curve of about $\frac{3}{8}$ of an inch to one minute of arc. The frame will be provided with suitable adjusting screws and be rigid enough to hold the level adjustment with rather severe usage. They must not project beyond the upper plate.

6. *The Telescope.*—The telescope should be provided with exceptionally good lenses so as to secure ample illumination, sharp definition and a flat field. The lenses should be free from chromatic and spherical aberration as far as practicable. The objective should have a clear aperture of $1\frac{5}{16}$ inches and focal length of $12\frac{1}{2}$ inches, and should be carefully centered. The eye-piece will be inverting and be well centered and mounted so as to be easily focused on the cross-hairs and at the same time be held in place so it cannot be lost. The focal length of the eye-piece should be about $\frac{5}{8}$ of an inch, with such magnifying power as will give the best results (see Wurdeman Theod., 154). The Steinhill lense may be used if it materially improves the telescope without a large increase in cost. The telescope wili have suitable focusing screw for objective, with proper rack motion which will move with little friction and no slip or lost motion. It will be provided with proper dust-cap and sun-shade. The diaphragm bearing the cross-hairs will be held in place by four adjusting screws, as is usual in the best transits. The cross-wires will consist of very fine smooth spider-web. There will be three horizontal wires and one vertical wire at right angles to the three wires. The intersection of the middle horizontal wire and the vertical wire will be in the center of the diaphragm. The distance between the extreme horizontal wires will be such that they will subtend on a rod a length of one foot at a distance of 120 feet. The intervals between the wires should be equal. All wires will be firmly fastened to the reticule or diaphragm, unless a satisfactory adjustment can be provided for stadia wires. The vertical motion clamp and screw will be in accordance with best practice.

7. *The Vertical Circle.*—The limb should be a full circle, 5 inches in diameter. The circle should be stiffened with a rib. (See Keuffel & Esser Catalogue, 1895, page 276.) The graduations should be on solid silver and be numbered from 0 to 90 degrees in both directions, starting

from two initial points, 180 degrees apart, and in a horizontal plane. (See Fig. 1, Keuffel & Esser Catalogue, page 284.) The circle will be divided into 20 minute spaces. Two double verniers will be provided. They will be so divided that 40 parts on the vernier will equal 39 parts on the limb, and read to half minutes. The verniers should be numbered at 5 minute intervals from zero each way to 20 minutes—the zeros of the two verniers being in a horizontal plane when instrument is leveled up. The horizontal vernier arm should bear a level about 3½ inches long, having a carefully ground glass with a curve of about ⅝ of an inch to a minute of arc. The level will be firmly fastened, and be provided with suitable adjusting screws at each end of the tube.

All graduations will be deep, full, smooth and distinct. Mere scratches on the surface will not answer.

8. *The Wyes* —These will be firm and substantial, and preferably only high enough to permit a telescope movement of, say 30 degrees in a vertical plane above and below the horizontal. A wye 4 inches high and with a 3-inch base would answer.

9. *The Foot-Screws.*—The instrument will be provided with four foot-screws covered with dust-caps at upper extremities.

10. *The Tripod.*—This will be provided with shifting head for quick centering, according to best practice. The legs of tripods will be 5 feet long.

11. *The Packing Box.*—The packing box will be made of white pine, a full inch thick, with dove-tailed corners, and the whole well oiled outside and in. The instrument will be screwed to a suitable base-piece so arranged to hold the instrument firmly in the box without additional packing. The box will be provided with suitable receptacles for plumb, bob, screw-driver and adjusting-pin and reading-glass 1½ inches in diameter, and these articles will be included with instrument. The box should be provided with lock and key.

12. The entire instrument will be made and finished in the best workmanlike manner throughout, and all material must be of the best. Where practicable, drawn or rolled metal will be used instead of castings for such parts as require rigidity.

DISCUSSION.

J. L. Van Ornum.—The writer cannot let the opportunity pass of commending this valuable paper, giving the result of the personal experience of Mr. Maltby with the stadia. It is always necessary to supplement theory with practice, and the experiences of the latter form

the most ready guide. Mr. Maltby has had a wide experience, not only in topographical surveys as such, but also in topography for special purposes (as the planning of irrigation systems), and commends thoroughly the use of the method in such cases. This coincides with the practice of Elwood Mead, State Engineer of Wyoming, who told the writer that he always used the stadia on surveys for irrigation projects. A member of this club has recently made a railroad preliminary survey by the same method. Its application in this field seems very advantageous over the old linear survey, and the result of that survey would make a valuable contribution, if the field location has been made so as to allow direct comparison with the topograpical preliminary.

While the one great argument for the stadia system lies in its ready application because of its making use of the ordinary transit and of very simple methods of observation, reduction and plotting, the fact should be thoroughly appreciated that it is capable of a still greater accuracy when occasion requires it. Those who have used the system can appreciate the advantages in this line, to be derived from the improved instrumental equipment mentioned in the paper. The dividing of the rod in true unit divisions (as also mentioned) comes into especial usefulness where greater accuracy is desired, as it enables the observer to read the vertical angle to the exact point of the rod at which he reads the distance, and so exclude the error caused by changing the pointing before reading this angle; it gives true distances on side-sights as well as station distances by causing the derived interval factor to change with the interval. Besides these advantages, those who have used the system count many others.

The writer cannot see the advantage of making the stadia-rod symmetrical about the center. He has used both rods so designed and rods having figures to aid in their reading, and it is his experience that the latter is more readily read. Of course, the use of figures necessitates the holding of one certain end always at the ground, but he has found a mistake in this regard extremely rare among rodmen. To reassure those who fear its occurrence, would it not be feasible to have the nail in the shoe of the rod (so generally used to aid in holding it vertical) placed only in one end, that end being the bottom?

The advocacy of sketching seems just. When it is considered that the purpose of topography is to show the surface as correctly as practicable from a framework consisting of comparatively few located points, showing the natural curves and gradual changes of slope instead of angles and abrupt changes that the rigid method requires, it seems desirable to indicate just the existing condition of these curves and slopes. Perhaps it could be described, but not as well, and the advantage of relieving the attention of the engineer of all the multiplicity of details

is applicable here. Instead of having to bear in mind a dozen details to be described in one way or another, he has only to make his sketch as he overlooks the ground, and these details appear without especial thought. Nor is it the writer's experience that it takes longer when one is accustomed to sketching than does a description, and it is more complete. Descriptions are not to be disregarded, for often they are most useful. But, as a rule, sketches seem desirable and at times a necessity. The method of sketching on detached sheets, as described in the evening's paper, seems excellent at times; still, circumstances will often put the sketches in the field-book, thus reducing the field-equipment and keeping all the field-notes together.

Methods and practice vary under differing conditions and with different men. In some cases it is desirable that it should be so; in others they may be improved upon. Thoughtful comparison and discussion will point out that which is best, and leave behind what is not well proved.

B. H. Colby.—Mr. Maltby's paper seems to me deserving of much commendation. It is practical from beginning to end. The reader is never in doubt as to the author's opinions or as to the reason for the faith that is in him. I am glad to see another experienced man come along and join the ranks of those who believe that it takes first-class instruments to secure first-class work.

Give a surgeon a sickle to amputate a leg, and he would not be more handicapped than a surveyor who is equipped with the ordinary transit and leveling-rod in making a topographical survey. To do good and rapid topographic work a stadia *board* at least 5 inches wide must be used. As well try to cut down trees with a jack-knife as to use a leveling-rod in taking topography.

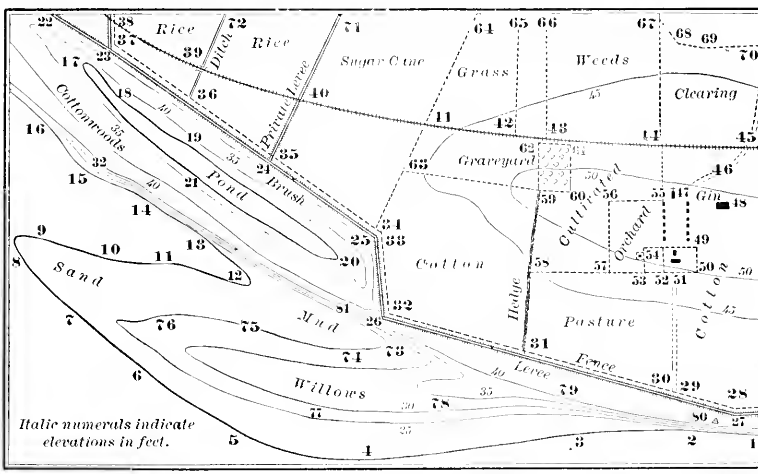
The points noted about the theodolite to be used are excellent. One of the most essential, to my mind, is that the vernier arm of the vertical circle shall have a level, attached to it and movable with it. With this attachment levels can be carried by vertical angles and stadia distances, when read both ways, almost as accurately as with the ordinary Y-level, and accurately enough for the requirements of any topographic survey. I think Mr. Maltby will agree with me in saying that levels can be run in this way within one-tenth of a foot to a mile. When the needle is used and distances and vertical angles are not read both ways, levels cannot, in my judgment, be depended upon unless the telescope is reversed at each station and the vertical angle read in both positions. The magnetic needle has had its day and should no longer be placed upon an instrument used for surveying.

I think the present high degree of accuracy obtained with the

stadia, could be materially increased by increasing the size of the telescope used.

I believe the time will surely come when the stadia will be used upon all railroad surveys, including preliminary lines and final estimates.

The good results obtained by Mr. Maltby are to be expected whenever and wherever such methods are followed. I am heartily in accord with nearly all the opinions and views expressed by Mr. Maltby, but I cannot agree with him in one detail, that of making field sketches. I would let his remarks in this regard pass unanswered were it not for the fact that he quoted me as having once written that: "Sketching is entirely useless, and worse than useless, as it is a waste of time." What I said in the paper quoted from is: "It seems to me that the time



an experienced topographic engineer spends in sketching is almost wasted."

Now I believe that whenever a surveyor is able to call off his "shots" to the recorder, using a nomenclature sufficiently comprehensive to enable any one at any subsequent period to accurately plat and properly connect with each other all the points and lines of the survey, that surveyor should not make a sketch. If he is not master of such a system of taking notes he is obliged to sketch to make his notes intelligible. I do not believe that there is any piece of ground, improved or unimproved, that cannot be surveyed, by stadia, and all of its features accurately located and mapped without making a sketch. The whole secret of topographic surveying without sketching is in taking the notes. A comprehensive system of nomenclature must be used. Such a system is very easy to acquire.

After making these statements it seems but fair to give some examples of the chief features of such a system, one that has been tested and found satisfactory in practical use. For a practical illustration I have taken a part of a topographic map* published by the Mississippi River Commission and furnished me by courtesy of Mr. J. A. Ockerson. On this map I have printed numbers from one to eighty-five inclusive, indicating different points located by stadia. These points would be designated in the "Object Column" of the note-book as follows:

1. Shore river, foot of bank.
2. Shore river, E. end sand bar.
3 to 10. Shore river, sand bar.
11. Shore river, sand and mud bar.
12. Shore river, mud bar.
13. Shore river, W. end mud bar.
14. Shore river, E. end sand.
15. Shore river, sand.
16. Shore river, W. end sand.
17 to 21. Water surface pond, cottonwood and brush.
22. Top levee, trees both levee sides.
23. Junction levee and levee No. 2, S.E cor. trees.
24. Junction and private levee, trees and brush S. of levee.
25. Levee bends, trees S.
26. Levee bends, trees end.
27. Levee bends, grass S.,cotton N.
28. Fence bends, cotton.
29. Fence E. S. road, cotton.
30. Fence W.S. road pasture.
31. Fence S. end hedge, pasture N. & E., cotton N. & W.
32. Fence bends, cotton.
33. Fence bends, W. edge cotton, E. edge sugar cane.
35. Fence & private levee, sugar N.E., rice N.W.
36. Fence and ditch 4′ wide, rice.
37. Fence bends, rice N.E.
38. Fence & R.R., rice E.
39. Center R.R. bridge (60′ x 30′) and ditch 4′ wide.
40. Center R.R. and private levee, rice W., sugar E.
41. Center R.R., sugar W., grass E.
42. Center R.R., grass W. & S., deadening E. & N.
43. Center R.R., deadening W., weeds E.
44. Center R.R. weeds N.W., clearing N.E., cotton S.E., cult. S.W.

* The fine detail of the original is omitted in the reproduction, as being non-essential to the discussion.—*Secretary, Ass'n of Eng. Socs.*

45. Center R.R. and road No. 2, clearing N., cotton S.
46. Center road No. 2, in cotton.
47. Center road No. 2, S. end, cotton.
48. N.E. cor. gin. (30′ x 75′).
49. N.E cor. d.y. fence, cotton.
50. S.E. cor. d.y. fence, cotton.
51. D.y. fence E. side road, cotton.
52. D.y. fence & cross fence, pasture.
53. S.W. cor. d.y. fence, pasture S., orchard N.W.
54. N.W. cor. d.y. fence, orchard W. of N.
55. N.E. cor. orchard, cotton N.E., cotton N.W.
56. N.W. cor. orchard, cultivated N. & W.
57. S.W. cor. orchard, cult. N.W., pasture S.
58. Hedge, cult. N.E., pasture S.E., cotton W.
59. S.W. cor. cemetery fence, N. end hedge, cult. S.E., cotton S.W., grass N.W.
60. S.E. cor. cemetery fence, cult.
61. N.E. cor. cemetery fence, cult.
62. N.W. cor. cemetery fence, grass.
63. Grass N.E., cotton S.E., sugar W.
64. Edge trees, grass S.E., sugar S.W.
65. Edge trees, deadening E., grass S.W.
66. Deadening W. & N., weeds S.E.
67. End fence, weeds W., cane and trees E., clearing S.E.
68–70. Fence bends, cane and trees N., clearing S.
71. Private levee bends, trees N.E., sugar E., rice W.
72. Ditch (4′) rice.
73. Mud and sand bar.
74–75. Mud and sand bar, edge willows.
76. Sand bar, end willows.
77. Sand bar, edge willows.
78. Sand bar, end willows.
79. Sand bar and grass.
80. Top bank, grass.
81. Top bank sand and mud bar, edge cottonwood trees.

By use of such a system as this the proper connections can be made between all the points of the survey with perfect accuracy. Abbreviations can be used to a much larger extent than I have indicated.

J. A. Ockerson.—Mr. Maltby has made a valuable contribution to the literature relating to the use of the stadia from a practical standpoint, in the paper presented to this Club. The theorist and the novice have given too much advice as to the use of the stadia. Most of them discover new devices for rods or new eccentricities of refraction, and between them lies largely the responsibility for the limited use of this most valuable method of making all classes of surveys.

Those of us who are familiar with the stadia and its great utility cannot be frightened by the hobgoblins conjured up by visions of "differential refraction." But the beginner will certainly hesitate to adopt an instrument which he is told gives one result in the morning and a different one at noon; one result on a cloudy day, another when the sun shines. This is true only in a limited sense. Before it means anything we must know what the limit of error allowable is. The chain as ordinarily used, gives the distance between two points with a certain degree of precision; with a steel tape a still better determination can be made; the same distance measured with a primary base apparatus will show that both chain and tape are in error, owing to variation in temperature, inclination, etc. This, however, is far from demonstrating that the chain and tape are not useful and valuable to the engineer, although it has been shown that the absolute length cannot be determined by their use. The same is true of the stadia. Because it has been demonstrated that measurements are probably not made with an accuracy of one in ten thousand is no argument against its use where an error of one in one thousand is inappreciable and not important. The stadia has been systematically slandered by holding up to view the fact that errors of small magnitude are continually occurring in measurements made by this method, at the same time obscuring the fact that such errors are wholly inappreciable in perhaps ninety per cent. of the work the surveyor has to do.

Those of us who have had the stadia in constant use for a quarter of a century, under a great variety of conditions, from the Great Lakes to the Gulf of Mexico, know, beyond the shadow of a doubt, that it is the only rational instrument to use in topographical work; that the degree of accuracy is well within the limits of errors in platting and change of scale in the paper itself; that attempts to go into refinements beyond these limits are more than useless, because the manipulation of rods and instruments in efforts to secure this imaginary increase in accuracy. tends to strip the stadia of its greatest charm and utility and add to the difficulties and expense of using it.

As an economical and expeditious method of locating points and obtaining their elevations for any purpose, whether it be for a topo-

graphical map, location of a railway or an irrigating canal, it stands without a rival.

The assertions here made as to the accuracy of stadia work cannot be successfully controverted, as they are amply verified by thousands of comparisons which may be found in our note-books covering a long period of time and a great extent of work.

The impossibility of defining a recognizable condition of atmosphere which would give absolutely uniform results in measurements; the infinite variety in atmospheric conditions and the brief existence of any one condition; the absolute necessity of being able to do work under any and all conditions; the small gain in accuracy derived from careful attention to the conditions of the air; all of these simply emphasize the facts that the best use is made of the stadia when the preliminary value of the wire interval is determined at any time when the conditions are not abnormal; that the work should continue daily without regard to whether the atmosphere is boiling or not; and that the final value for the wire interval shall be derived from comparisons of the stadia lengths between fixed points, as measured under all of these constantly varying conditions, with the true lengths as determined by triangulation or other rigid methods.

In the great majority of cases, the preliminary value of the wire interval will answer all requirements.

The cost of topographical work will depend largely on the amount of detail required and the scale on which it is to be mapped.

In the survey of the Mississippi River all features, natural and artificial, that will show on a scale of 1:10,000 are located instrumentally and sufficient elevations are determined to develop contours of elevation 5 feet apart. The shore line of the river, islands, sand-bars, tertiary triangulation, etc., add considerably to the work and should be taken into account when comparing with cost of other work per square mile. About 1,000 square miles of topography lying along both banks of the river from Alton northward and including several cities, like Hannibal, Quincy, Keokuk, Burlington, etc., cost an average of $39.46 per square mile, or about six cents per acre. The number of points located per square mile averaged 371.

Platting the notes and drawing the maps complete on a scale of 1 : 10,000, cost about five dollars per square mile.

Printing an edition of 1,000 copies on a scale of 1 : 20,000 sheets 22 inches by 36 inches inside of border, cost about five dollars per square mile.

Mr. Maltby is entitled to the thanks of the profession for his advocacy of the utility of the stadia for surveys in general, and his experience should endow his views with great weight.

For fear this discussion may be considered as endorsing or advocating loose and careless work, it may be said that the writer is a firm advocate of careful and accurate work, but considers it quite as grave an error to carry the refinements of a work, at the expense of time and money, far beyond all reasonable requirements, as it is to fall a trifle short in such requirements. The work should be just as accurate as the uses to which it is to be put require; no more, no less. The conscientious engineer will strive to come as near this golden mean as practicable. His departure from it will stand as a measure of his skill, judgment and comprehension of the requirements.

Yours truly
J. F. Holloway

Honorary Member and Ex-President of the Civil Engineers' Club of Cleveland.

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ERRATA IN OCTOBER NUMBER.

Page 119, Fig. 3, title: For "Vicensa" read "Vicenza."

Page 132, 9th line: For "Michael Angelo" read "Antonio da Ponte"

Page 138, Fig. 20, title: For "Bridge over the Nydeck" read "Nydeck Bridge over the Aar."

Page 139, last line: For "Maritime Alps" read "Pyrenees."

Page 140, 5th line: For "Morlaux" read "Morlaix."

Page 141, Fig. 23, title: For "Morlaux" read "Morlaix."

principle it is not in any sense a true arch. These false arches were used by the Egyptians, the Assyrians, the Greeks, and other older nations. Fig. 1 shows a Greek structure of this kind.

The principle of the arch appears to have been known to the Assyrians and to almost all of the older nations whose structures have become known to us. All of the Assyrian arches thus far discovered are of brick, the bricks being made of a wedge shape, or thicker at the outside than at the inside. Most of the arches were semicircular, and the maximum span found is 15 feet. The only pointed arch discovered in the Assyrian ruins is built of brick of the ordinary shape, the joints being thicker on the outside; while instead of the keystone, ordinary bricks were laid longitudinally between the two sides. The arch was used by

* Manuscript received September 29, 1896.—*Secretary, Ass'n of Eng. Socs.*

Yours Truly
J. F. Holloway

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VOL. XVII. OCTOBER, 1896. No. 4.

THE HISTORICAL DEVELOPMENT OF STONE BRIDGES.

BY PROF. GEORGE F. SWAIN, PRESIDENT OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Lecture delivered before the Society, June 17, 1896.*]

THE first stone bridges were simply blocks of stone laid horizontally over an opening. Such bridges are still used for spanning narrow openings, and in some countries for crossing streams of not inconsiderable width. In buildings, this is still the most common mode of spanning an opening. The next step was to corbel out, letting one stone project beyond the one beneath it, and in this manner spanning larger openings than would be possible with one stone alone. The next step was to cut off the lower projecting corners of these corbelled stones, making a structure in appearance like an arch—a so-called false arch—though in principle it is not in any sense a true arch. These false arches were used by the Egyptians, the Assyrians, the Greeks, and other older nations. Fig. 1 shows a Greek structure of this kind.

The principle of the arch appears to have been known to the Assyrians and to almost all of the older nations whose structures have become known to us. All of the Assyrian arches thus far discovered are of brick, the bricks being made of a wedge shape, or thicker at the outside than at the inside. Most of the arches were semicircular, and the maximum span found is 15 feet. The only pointed arch discovered in the Assyrian ruins is built of brick of the ordinary shape, the joints being thicker on the outside; while instead of the keystone, ordinary bricks were laid longitudinally between the two sides. The arch was used by

*Manuscript received September 29, 1896.—*Secretary, Ass'n of Eng. Socs.*

the Assyrians for doors, gates, drains, aqueducts, and chambers or galleries.

Still earlier than the Assyrian arches, which belong to about the ninth century B.C., were the brick Babylonian arches, as early as 1300 B.C., while in Egypt arches were known as far back as the fifteenth century B.C. The early Egyptians, however, though undoubtedly acquainted with the arch principle, avoided arches, and seem not to have fully grasped the idea of using a large number of thin stones laid with the long sides touching. The Hindoos to this day refuse to use arches. They have a saying that "the arch never sleeps," meaning by this that it continually exerts a horizontal thrust upon its supports, tending to disintegrate and destroy them. This quaint saying is true and suggestive. The arch will not withstand the ravages of time as well as the structure which causes only vertical pressures upon its supports. Any yielding, decay or defect may result in the collapse of the entire structure. The Egyptians, then, who

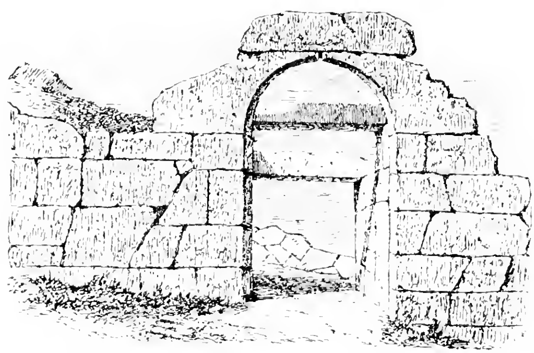

FIG. 1.—GREEK FALSE ARCH.

also attached weight to this principle, never applied the arch on a large scale, or to large edifices.

To the Romans is due the special development of the arch, and its application on a large scale in the construction of viaducts, aqueducts, sewers, buildings and bridges. One of the earliest of their arches was the Cloāca Maxima, a sewer which is still in use and in good condition. The arch consists of three rings of stones, and its construction shows a perfect appreciation of the principles involved. The Romans built many arch bridges over streams, one of the bridges over the Tiber having a span of 84 feet; while the Emperor Augustus constructed a bridge of five spans over the river Marachia at Rimini. Between Rome and Gābii there was a viaduct with nine arches. Fig. 2 shows one of the early Roman bridges across the Tiber, while Fig. 3 shows another typical Roman bridge of three

spans at Vicenza, and Fig. 4 still another early Roman bridge, with triumphal arches over the roadway at each end.

The ancient Romans, while they built a large number of bridges,

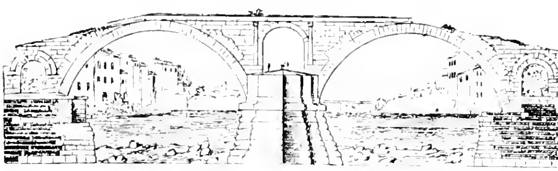

FIG. 2.—FABRICIUS BRIDGE AT ROME.

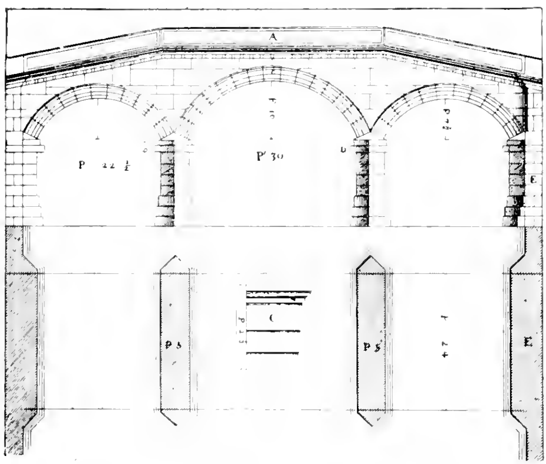

FIG. 3.—OLD ROMAN BRIDGE AT VICENSA.

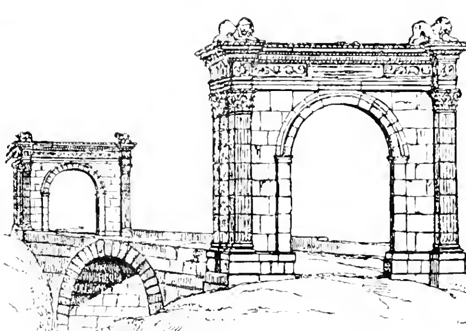

FIG. 4.—BRIDGE OF ST. CHAMAS.

aqueducts, and other works of this nature, met with difficulties in the foundations of their bridges over streams. Where they were able to build upon a rock foundation they constructed works which have en-

dured, and by giving considerable width to the piers of their bridges across streams or on soft ground, they succeeded in meeting temporarily the difficulties attendant upon a foundation on compressible material; but they were not able to protect themselves sufficiently against the effect of floods, and the excessive width of their piers, by diminishing the waterway, greatly increased the danger of undermining, which has been the cause of the destruction of most of their bridges. The piers, whose thickness was, on an average, one third of the span, were not carried sufficiently deep; the riprap or stone filling by which they were protected was not effective; in a word, their foundations were imperfect.

The arches of the Roman bridges were almost always semicircular; in exceptional cases they adopted flattened curves, whose rise was never made less than one third of the span. In general the extrados was parallel to the intrados, and the thickness of the arch ring at the crown was on an average about one twelfth of the span.

The number of arches in the Roman bridges was generally uneven, and the central arch had a larger span than the others. Often the spans decreased progressively from the center of the bridge to the ends. Under these conditions the roadway above could only be made horizontal, with the same depth of filling above each arch, when the springings of the arches were placed at different levels, and higher towards the ends. In general, however, they preferred to place the springing lines of all the arches at the same level, making the roadway inclined from each end towards the center, sometimes with an angle at the center, and sometimes with a horizontal portion above the center span. The contraction of the water-way due to the thickness of the piers was in part made up for, in some cases, by openings through the masonry above the piers or in the haunches. (Fig. 2.) But while the excessive thickness of the piers of the Roman bridges had the effect of increasing the danger of undermining, it resulted in the advantage that each pier was able to resist the thrust of the arch on either side of it, even though the arch on the other side should be destroyed. The fall of one arch, therefore, did not result in the fall of the adjacent arches, as would be the case in many modern bridges. The piers were made triangular at each end, or sometimes semicircular. The bridges carrying roads were provided with continuous solid parapets.

In the arches, as well as in the other masonry structures of the Romans, the stones were laid dry, that is, without beds of mortar. Moreover, each arch was frequently made up of several rings of arch stones not bonded, or connected together in any way. Some of these bridges are still in existence and differ comparatively little from modern structures. Many of these Roman bridges were adorned with statues on the piers and on the approaches.

The most important of the Roman bridges, however, were in connection with the aqueducts which supplied the cities with water. There were nine of these aqueducts supplying ancient Rome in the time of Frontinus, "Curator Aquarum" from 97 to 106 A.D. The first was underground and was built by Appius Claudius 312 B.C. The second was also underground and was built forty years later. The third, or Martian aqueduct, was built 144 B.C., by Quintus Martius, and was partly

FIG. 5.—CLAUDIAN AQUEDUCT CROSSING THE CAMPAGNA, AT ROME.

above ground, and its remains may still be seen. It had nearly 7,000 arches in a course of 39 miles, with spans of 16 feet. It was constructed of different kinds of stone, red, brown and yellow. The arches in many places were more than 70 feet in height. This aqueduct was built so strong that the two succeeding ones were built on top of it, thus giving three tiers of arches, one above the other. The sixth aqueduct was constructed by Agrippa, in 33 B.C. The seventh was built by Augustus. The eighth, or Claudian aqueduct, 45 miles long, and the ninth, 62 miles long,

were both begun by Caligula, A.D. 38, and completed by Claudius, A.D. 52. Along the greater part of their course they are carried on the same line of lofty arches with spans of about 20 feet, the highest of all the aqueducts supplying Rome. Magnificent remains of the Claudian aqueduct, built of massive blocks of tufa, still exist for many miles across the Campagna. (Fig. 5.) "A great number of these arches are still in good preservation, with, in places, later arches built under them by Severus in 201, probably to support them after injury by an earthquake." (Middleton.) Two other aqueducts were built later, the Aqua Trajana, built by Trajan, A.D. 109; and the Aqua Alexandrina, built A.D. 226, by Severus Alexander.

In addition to the aqueducts which supplied Rome, the Romans built many other aqueducts, among which may be specially mentioned that at Nismes, in Southern France, and those at Segovia and Tarragōna, in Spain. The noted Pont du Gard (Fig. 6) was built in the aqueduct supplying Nismes, and is one of the earliest aqueducts constructed by the Romans outside of Italy. It is supposed to have been built in the time of Augustus. This aqueduct had three tiers of arches, but only one channel at the top. The length of this bridge at the top of the second tier is 885 feet, and its maximum height over the river Gardon is about 160 feet. The arches of the two lower tiers are semicircular. The large arch, through which the river passes, is 80 feet 5 inches in span; the three on the right side of this are 63 feet, and the smaller ones 51 feet; the arches of the upper tier are all equal in span, 15 feet 9 inches. The thickness from face to face is at the first story 20 feet 9 inches, at the second story 15 feet, at the third 11 feet 9 inches. The depth of the keystone of the large arch is 5 feet 3 inches; that of the others 5 feet, while those of the upper story are 2 feet 7 inches. The lower arches are formed of four separate rings, the next above of three, and the upper of one. The arches thus consisted of separate narrow arches side by side, not bonded or connected together. This structure is constructed of freestone with rubble filling in the piers and spandrels. The stones were laid without cement, and projecting stones were left to support the centers. The dimensions of the channel are 4 feet wide and 4 feet 9 inches high. Above the small arches of the upper tier cement was used in the rubble masonry about the channel. This cement has become as hard as the stone itself, forming one impermeable mass, and preventing any filtration. This beautiful structure was partly destroyed at the ends, at the beginning of the fifth century, by the barbarians who besieged Nismes. In 1743 it was repaired and the piers prolonged to carry a new bridge. The entire length of the aqueduct of which this bridge forms a part is over 25½ miles. The fall given to the water along the entire length is 0.04 feet per 100 feet, and is uniform throughout. This

great work of engineering will compare favorably with any of modern times. It shows that the Romans understood thoroughly the art of leveling, and much more of the science of hydraulics than we generally credit them with. Considering the state of physical science at that time, the skill and care displayed in this and other similar works is little short of marvelous.

The aqueduct of Segovia, Spain (Fig. 7), was built by the Emperor Trajan, and is of squared stone laid without mortar, crossing a valley

FIG. 6.—PONT DU GARD, AT NISMES.

with a length of more than 2,500 feet. It is in many places nearly 100 feet high. This aqueduct has 109 arches, of which 30 are modern, but like the old ones. It has carried water up to a very recent date, and possibly may still be in use. The aqueduct at Tarragōna is similar, and of about the same height, with 25 lower arches and 11 upper arches.

One of the most famous Roman bridges is the Bridge of Alcantara, across the Tagus near Alcantara, close to the frontier between Spain and Portugal. It is said to have been built by Trajan about 98 A.D., and

had six semicircular arches, with one center span of 115 feet, with a height of 203 feet above the river. The masonry was dry.

Another work which is sometimes described is the so-called mole of Caligula, the remains of which may still be seen in the bay of Pozzuoli, near Naples, and which is thought by some to have extended entirely across the bay to Baie. Thus Palladio, writing in 1570, said: "But among all of the celebrated bri lges, that is recorded as a marvelous thing which Caligula made from Pozzuolo to Baie in the middle of the sea, in length

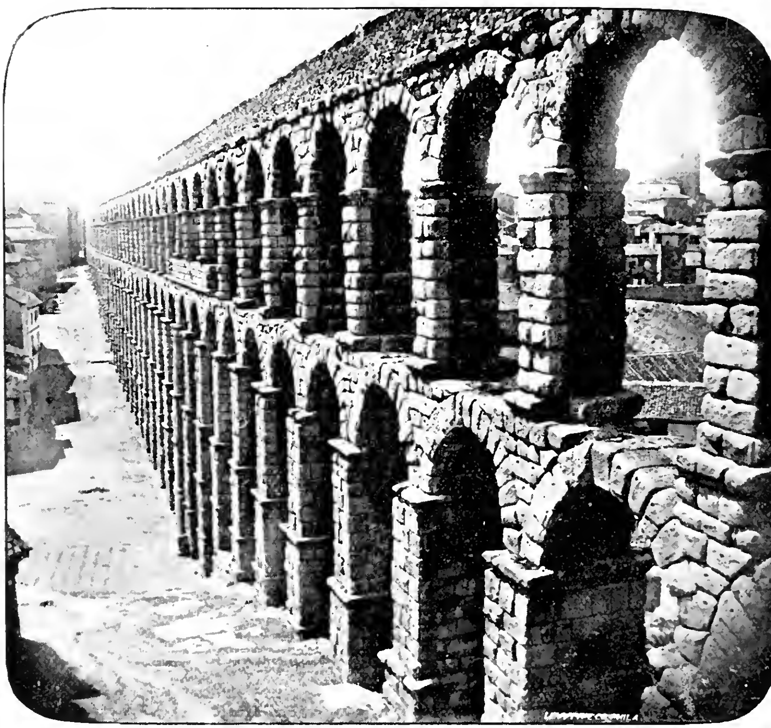

Fig. 7.—Old Roman Aqueduct at Segovia, Spain.

somewhat less than three miles; in which they say he spent all the money of the Empire." The history of this work, however, is imperfect and confused; no one knows who built it or conceived it, and it was already in a considerable state of dilapidation at the time of Hadrian, so that it appears certain that Caligula did not build it or even repair it, but at one time had a bridge of boats constructed across the bay from its seaward extremity, upon which he built a paved roadway similar to the Appian way.

It is evident from these examples that the Romans were masters of the science of engineering so far as concerns the construction of stone bridges and of aqueducts, and history shows that their skill extended to other branches as well.

After the fall of the Western Empire there was little bridge building in Europe until the twelfth century, when the increase of travel, together with the rapid development of cities and of trade, rendered imperative better facilities for crossing streams.

FIG. 8.—BRIDGE OF ST. BENEZET, ACROSS THE RHONE AT AVIGNON.

In France a religious association known as "Brothers of the Bridge," was founded by Benedictine monks, and flourished especially during the twelfth and thirteenth centuries. By this order the building of bridges was assumed as an act of piety. They established houses for the accommodation of travelers at the stream crossings, acquired means for constructing bridges, and in some cases superintended their erection. One of the earliest bridges built by this organization was at Durrance, but due consideration not having been given to the waterway, it

was soon demolished by floods. Another, known as the Bridge of St. Benezet (Fig. 8), and the funds for which were obtained by a pretended miracle, was built at Avignon, over the Rhone, having been begun in 1177 and completed in 1187. This bridge is said to have had twenty-two arches and was 2,000 feet long, and only 13 feet wide between parapets. The largest span was about 110 feet, and the arches were segmental. In 1385 Pope Boniface IX had some arches of the bridge destroyed for his own safety, and various mishaps resulted in the destruction of others. In 1410 the inhabitants blew up the tower, which carried down three other spans, and in 1670 the river carried away several more. There are now only the remains of a few arches.

Many other bridges were built by the "Brothers," among which may be named those of St. Esprit, Ceret, Nions, Castellane, Villeneuve d'Agen, and a remarkable bridge at Vielle Brioude, over the Allier, built 1454, with one arch having a span of 183 feet, and a rise of 70 feet. Only the arch ring was of cut stone, and it was quite thin, the rest of the masonry being of rubble. The piers above high-water were faced with stone on the outside, the inside being filled with sand and gravel. This bridge was reconstructed about the middle of the present century.

Of all these bridges built between the twelfth and sixteenth centuries, it may be said that it is remarkable that they stood as well as they did. They were cheaply constructed, and very narrow, seldom 20 feet in width, generally not over 13 to 16 feet, and sometimes but 6 or 7; the piers were very thick, and the spandrels either perforated, or filled with earth.

In several bridges of this period Gothic or pointed arches were used. Thus the bridge over the Ticino, at Pavia, built in the fourteenth century, under Galeas Visconti, Duke of Milan, had seven equal spans of 70 feet with a rise of 64 feet. The piers were about 16 feet thick. This bridge was built of brick, and was covered, the roof being supported by marble columns. It is, however, not now in existence. The present structure is itself several centuries old, and has six arches, the maximum span being 100 feet.

Other notable bridges of the Middle Ages were the bridge over the Danube at Ratisbon, built in 1133, with fifteen semicircular arches varying in span from 33 feet to 53 feet; the bridge over the Elbe at Dresden, built in the twelfth century and restored about 1730, in which the thickness of the piers was almost as great as the spans of the arches; the old bridge over the Moldau at Prag; and the old bridge over the Main at Würzburg. Fig. 9 is a view of the Karlsbrücke at Prag, showing principally the tower at the end. This bridge has sixteen spans, and was built between 1357 and 1507. It was partially destroyed by a flood in 1890. As shown in the picture, it is ornamented by thirty statues and

groups of saints, including a bronze statue, in the center, of St. John Nepomuc, the patron saint of Bohemia, in whose memory the bridge is visited yearly by thousands of pilgrims. The saint is said to have been flung from the bridge in 1383, by order of the Emperor, for refusing to betray what the Empress had confided to him in confessional. The body is said to have floated for some time in the river, with five brilliant stars hovering over the head.

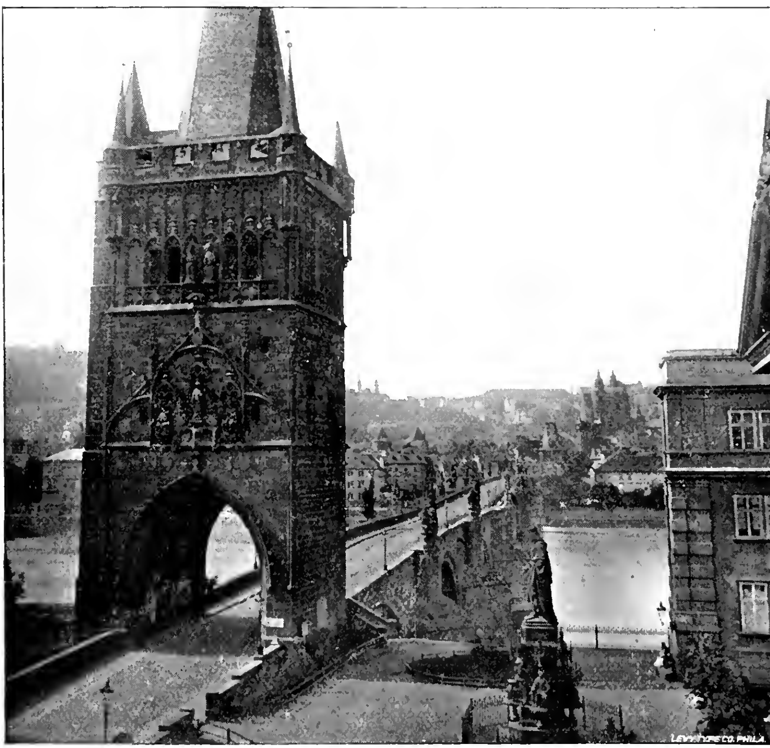

Fig. 9.—Karlsbrücke at Prag.

Fig. 10 shows an old bridge at Kreuznach, with buildings over the piers.

Perhaps to us the most interesting bridge built within this period is the old London bridge over the Thames, built by Peter of Colechurch. This bridge was begun in 1176 and finished in 1209, and was 926 feet long and 40 feet wide. It contained a drawbridge and nineteen pointed arches, varying in span from about 9 feet to 20 feet, with massive piers, varying from 25 feet to 34 feet wide. The obstruction caused by these

huge barriers, and the large number of piers, reduced the entire channel of the river from its normal breadth of 900 feet to a total waterway of 194 feet, or less than one-quarter. It is said that this obstruction caused a fall of water at the bridge of about 5 feet. Only eighty years after its completion this bridge was in such bad condition that men were afraid to pass over it, and the houses on top had arches built between them to hold them together. In 1758 the houses were removed, and a large arch constructed in place of two smaller ones. In 1738 the West-

FIG. 10.—ANCIENT BRIDGE AT KREUZNACH, GERMANY.

minster bridge was begun, and completed in 1749. This was the second bridge over the river; but it did not relieve the traffic sufficiently, and repairs were made on the London bridge, at a cost of £100,000. In 1824 to 1831, the new London bridge was built, consisting of five semi-elliptical arches, with two spans of 130 feet, two of 140 feet, and the central one of 152 feet 6 inches, and a rise of 37 feet 6 inches. This was the largest elliptical arch built up to that time.*

* The roadway of this bridge was 52 feet wide. It was built just above the old bridge, and was designed by John Rennie, and built by his sons, John Rennie and Sir George Rennie, at a cost of £426,000.

To the mediæval period belongs also the Ponte Vecchio, over the Arno, in Florence, built originally in 1177, but reconstructed in 1345. It has three segmental arches, with spans of from 85 feet to 94 feet 6 inches, piers 20 feet 4 inches thick, and a depth of keystone of 3 feet 3 inches. Its breadth is 105 feet, and it carries a covered gallery, constructed by the Medici, forming the continuation of a passage from the Pitti palace to the old Ducal palace, with stores on the sides, originally

FIG. 11.—BRIDGE OF ALCANTARA, TOLEDO, SPAIN.

intended for goldsmiths' shops. This is one of the first mediæval bridges which is segmental.

The largest stone arch span constructed up to the present day was found in a bridge built in 1377 by Barnabo Visconti, at Trezzo, over the Adda, which was destroyed in a local war in 1416. It was fortified, and defended the approaches of the castle of Trezzo. It was a segmental arch, with a span of 237 feet and a rise of 68 feet.

In Spain, the Middle Ages saw the construction of several remarkable works. The bridge of Alcantara, over the Tagus at Toledo (Fig. 11),

was built in 997, and has one large span of 93 feet, adjoining which is a small span of 52.5 feet, both semicircular. The tower has a Moorish aspect, but the general character of this structure is Roman.

The St. Martin bridge, over the same river and in the same city (Fig. 12), built in 1203, is still more picturesque. The central arch is pointed, with a span of 132 feet, though the angle at the top is scarcely perceptible. Of the adjacent arches, some are pointed and some semicircular.

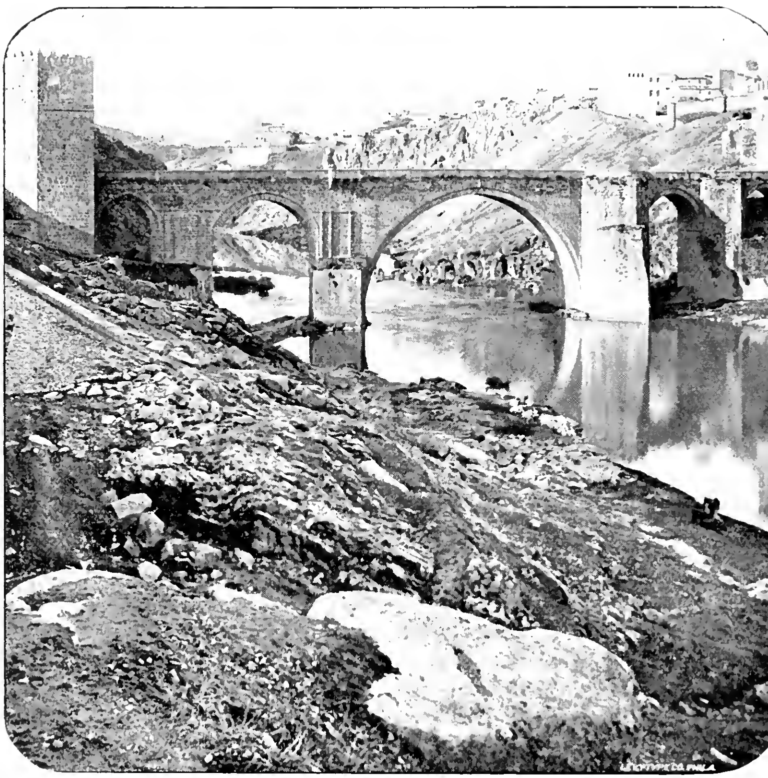

FIG. 12.—ST. MARTIN BRIDGE, TOLEDO, SPAIN.

In comparing the bridges of the Middle Ages with those of the Romans, we see that those of the Middle Ages had often much steeper approaches, narrower roadways, and that the spans of the arches of the same bridge were very unequal. The shape of the arches remained, for the most part, as with the Romans, semicircular or but slightly depressed, though sometimes pointed and sometimes segmental, and the piers were very thick and pointed. At the ends were frequently towers

or chapels (Fig. 13), either for purposes of defense or to commemorate the religious origin of the structure. While the workmanship was sometimes good, it was generally coarse and defective to such an extent that it is difficult to understand why some of them have stood until the present day. Some of them were remarkable for length of span, and for small thickness of the arch ring, as well as for small width.

In the sixteenth and seventeenth centuries many bridges were

Fig. 13.—Bridge at Tournai, Belgium.

built, particularly in France and Italy. After the collapse of the old Pont Notre Dame in Paris, in 1498, the new structure, which still exists, was begun, and completed in 1507, and this was followed by the construction of several other stone bridges in Paris. The Pont Neuf was begun in 1578 and completed in 1604; the Pont St. Michel in 1617, the Pont Marie in 1635, the Pont au Change in 1639, and the Tournelle in 1656. These bridges still exist, although, to provide for the increase in traffic, the Pont St. Michel was rebuilt in 1859 and the

Pont au Change in 1858, in each case the number of spans being reduced and the width increased. The Pont de la Tournelle was widened in 1845 by the addition of cast iron arches.

In Italy, the Trinity bridge at Florence (Fig. 14), built in 1570 by Ammanati, and the Rialto bridge over the Grand Canal at Venice, completed in 1590, belong to this period. The Trinity bridge has three nearly elliptical arches, from 87 feet 7 inches to 95 feet 10 inches in span, and piers 26 feet 3 inches thick. The Rialto bridge, built 1578 by Michael Angelo, has one segmental arch with a span of 96 feet 10 inches, and a rise of 20 feet 7 inches. The approaches are steep, with

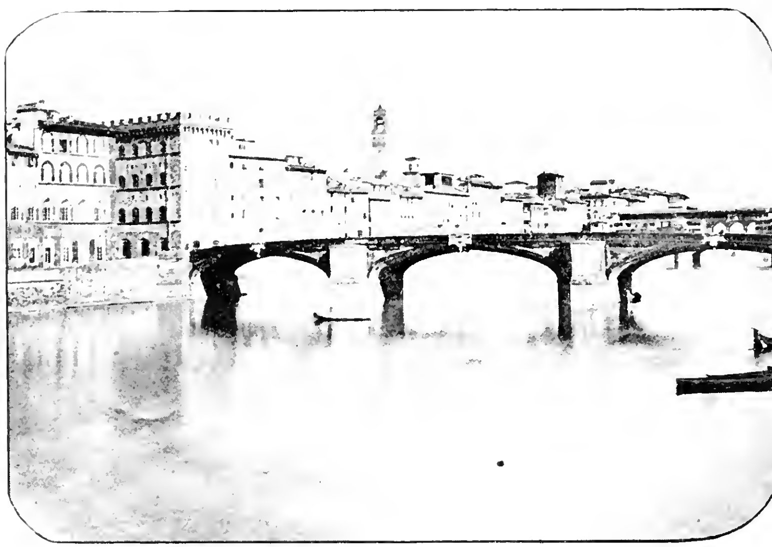

Fig. 14.—Trinity Bridge at Florence.

marble steps, and there are stores on each side of a central passageway.

At this time, it will be remembered, the use of very flat arches was considered a bold undertaking, and the Fleischbrücke (or Pont des Boucheries), in Nüremberg, built in 1599, by Peter Carl, consisting of a single arch with a span of 97 feet, and a rise of only 13 feet, or less than one-seventh of the span, was considered a very bold structure. The thickness of the keystone of this bridge was 4 feet; the abutments were built with joints in continuation of the arch, and were founded upon piles driven obliquely.

In the sixteenth and seventeenth centuries, then, the principal development appears to have been in the increasing use of elliptical, seg-

mental, or other flattened curves instead of semi-circular arches, and in the increased care devoted to construction and to ornament. Worthy of note, too, is the improvement gradually being made in the foundations of bridges. The structures of earlier date had generally been founded on stone filling, and the piers had been necessarily thick, in order to distribute the load. The later bridges were founded upon pile platforms, or in caissons; while in the bridge over the Maas at Masstrecht, begun

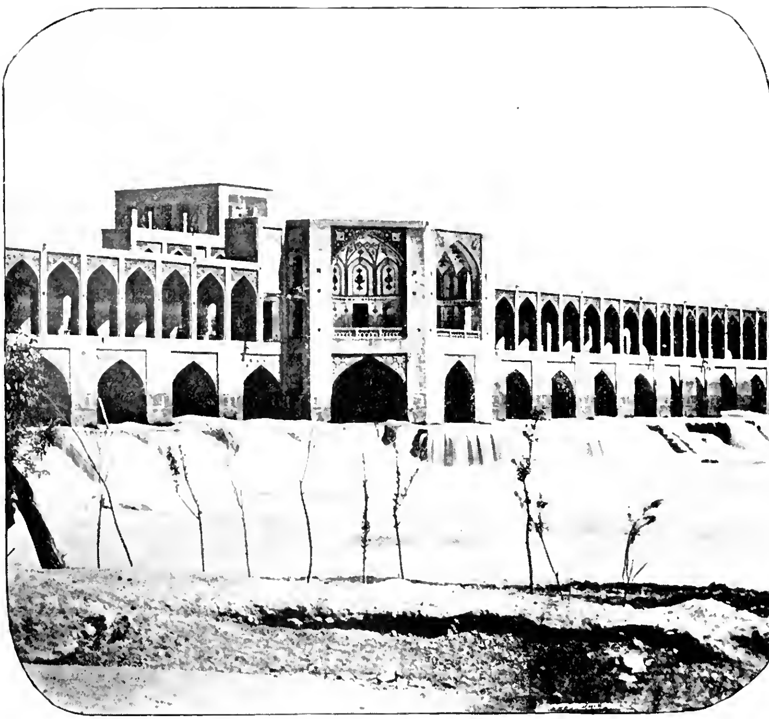

Fig. 15.—Bridge at Ispahan, Persia.

in 1683 by the Dominican monk Romano, the first dredging machine is said to have been employed.

Fig. 15 shows the bridge of Allah-Verdi-Khan, at Ispahan, which has thirty-three arches of about 18 feet span, and three smaller arches at the end, all pointed, and of true Persian character.

Fig. 16 shows a bridge in China, which, in its steep approaches, reminds us of some of the mediæval bridges of Europe. The dates of these bridges are uncertain.

In the eighteenth century a great impetus was given to the rational

and æsthetic design of bridges by the establishment (in 1716) in France of the Corps des Ponts et Chaussées, or government engineers of bridges and roads. Gabriel was placed at the head of the corps, being the first engineer-in-chief. Most of the bridges of the older period—those built by the Romans and by the "Brothers"—had tumbled down, and many new bridges were needed. From this time development was very rapid. After Gabriel's designs, the bridge of Blois, over the Loire, was built by Pitrou, in 1720, consisting of eleven flattened arches, with

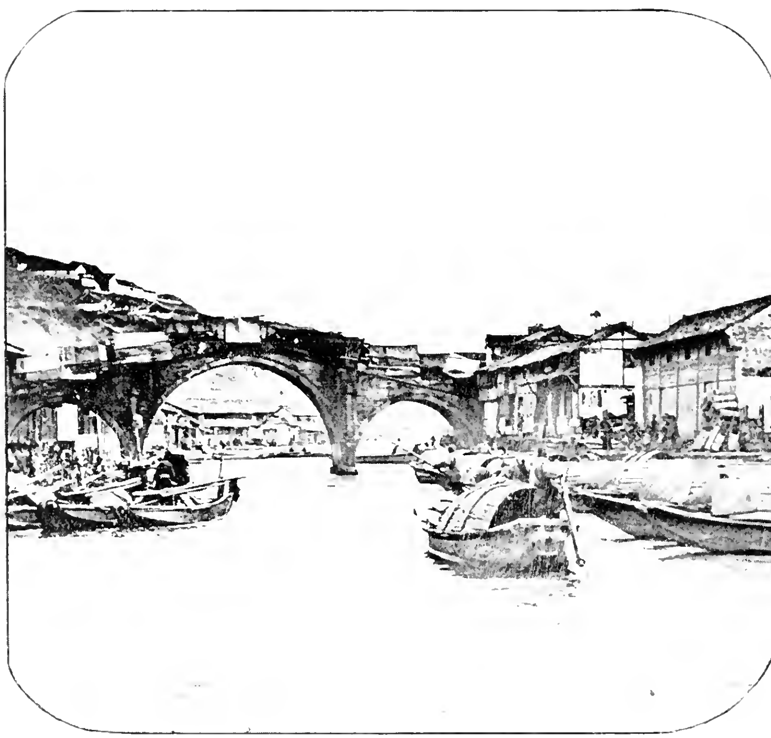

Fig. 16.—Chinese Bridge.

spans increasing from 55 feet at the ends, to 86 feet at the center, the grade of the approaches being as great as in many of the older bridges. In this bridge, for the first time since the old Roman days, the centers were supported entirely at the ends, without any intermediate supports whatever. In the bridge at Saumur, a saw was invented for cutting off piles under water at a considerable depth (16 feet), while in the Westminster Bridge, at London, built in 1738, by a French engineer, Labelye, caissons of the modern kind were used for the first time, being sunk upon a prepared foundation of piles covered by a platform.

In 1760, the École des Ponts et Chaussées, originally started in 1747 as a drawing school, was organized for the training of engineers, and the noted engineer, Perronet, was placed at its head. From that time to this the great majority of the public works of France have been built by its graduates, and it is not too much to say that its establishment gave to France that pre-eminence in engineering which she enjoyed for so many years. Perronet's bridge at Neuilly, across the Seine, consisting of five spans of 128 feet, completed in 1774, and justly considered the masterpiece of its builder, was distinguished by the first use of what are known as cow-horns, the object of which is to facilitate the passage of floods and debris under the arches. Segmental arches, of course, owing to the fact that they are not vertical at the springings, but rise gradually, offer more obstruction to the floods than elliptical or basket-handle arches. For this reason, where used, their springing had thus far generally been placed higher than when other forms were used, often much above ordinary high water. After the introduction of cow-horns, by Perronet, in the Neuilly bridge, however, segmental arches were soon used with the springing at the high water-mark, or even below it. The use of cow-horns, moreover, gave an appearance of lightness, even though the arch ring might be thicker than usual towards the abutments. The Neuilly Bridge was of the basket-handle type, with piers semicircular at each end and 14 feet thick. It was founded on piles. Fig. 17 is the bridge at Bordeaux, with cow-horns.

The Pont de la Concorde, in Paris, begun 1787, has five flat segmental arches, with spans from 83 to 102 feet, supported by very slender piers only 10 feet thick, which would doubtless be unable to stand if one arch should fall. This small thickness facilitates the passage of the water, and gives the lower portion of the bridge an appearance of lightness which, however, is destroyed by the heavy treatment of the tops of the piers and the roadway.

To the eighteenth century belong some of the most noted stone bridges of England.

The old Westminster bridge, at London, completed in 1750, was the first bridge in which caissons were used in founding the piers. A settling of one pier, however, required the taking down and rebuilding of the two adjacent spans. This bridge had thirteen semicircular arches with a maximum span of 72 feet. It stood for about a century, till the demands of traffic led to its being replaced by a cast-iron bridge of seven spans, 85 feet wide.

The old Blackfriars bridge, built by the Scotch engineer, Mylne, from 1760–1769, had nine basket-handle arches, with a maximum span of 100 feet and a rise of 40 feet. It was 995 feet long and 45 feet

wide, and was handsomely decorated with double columns over the piers. The bridge cost £152,840. Owing to settling, however, and also, it is said, to the use of poor stone, it was necessary, in 1833, to repair the bridge at a cost of £105,138. Even then it was not satisfactory, and in 1865 it was replaced by a cast-iron arch bridge of five spans, designed by Joseph Cubitt.

The bridge across the Thames, at Kew, is still in existence, and though its dimensions are but moderate, it was carefully and solidly constructed.

Fig. 17—Bridge at Bordeaux, France.

Worthy of mention is the bridge over the Taaf, at Pony-y-Pridd, in Wales. In 1746 a mason, W. Edwards, built an arch bridge here of three spans. After two and a half years it was carried away by a freshet, and being guaranteed for seven years, Edwards had to rebuild it, and did so, using a single arch. It was completed, but the parapets had not been put on, when the load on the haunches threw up the crown and the arch fell. Mr. Edwards consulted Smeaton and rebuilt it as before, in 1748, but with openings in the haunches. The span is 140 feet, and the rise is 35 feet, and the thickness of arch ring at the crown 2.5 feet.

The aqueduct at Alcantara, near Lisbon (Fig. 18), is attributed by Gauthey to Trajan, but in reality the Romans made scarcely the beginning, and it was not until 1731 that the work was really begun. It had been nearly completed at the time of the terrible earthquake of 1775, which destroyed the greater part of the city. The aqueduct, however, was so solidly built that it was little injured, and, moreover, it was somewhat distant from the center of disturbance. This aqueduct contains

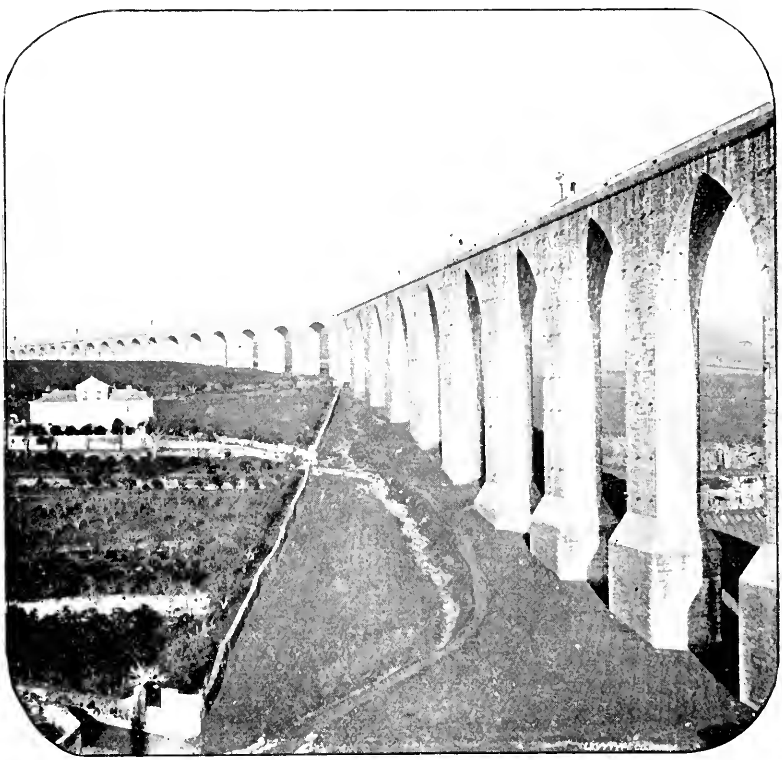

FIG. 18.—AQUEDUCT NEAR LISBON, PORTUGAL.

35 arches, the central or largest opening with a pointed arch of 100 feet span and 88 feet rise. The height of the intrados of this span at the crown is 197 feet above the river, and the maximum height of the structure is 230 feet. This is said to be the highest existing arch bridge having but one tier of arches.

The principal progress during the eighteenth century appears to have been in the increased use of elliptical or other flattened arches, the reduction in the ratio of rise to span, the use of segmental arches

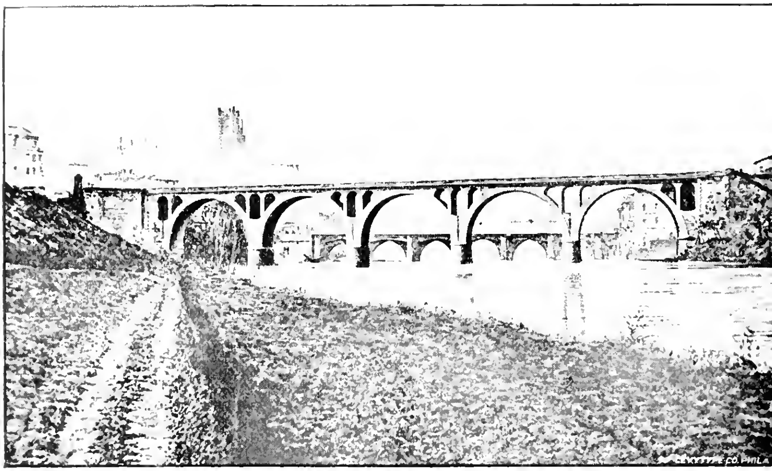

FIG. 19.—PONT NEUF AT ALBI, FRANCE.

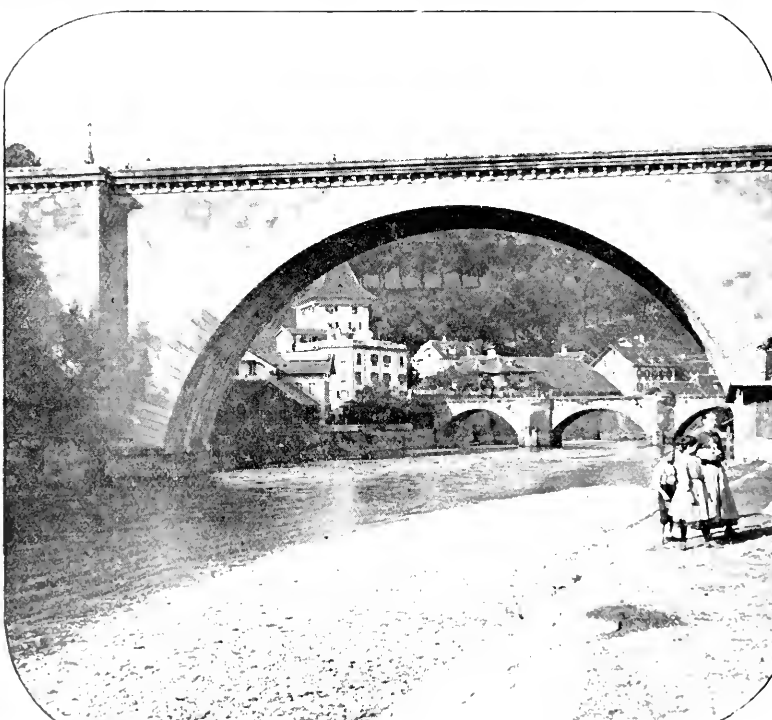

FIG. 20.—BRIDGE OVER THE NYDECK, AT BERNE, SWITZERLAND.

with cow-horns, the gradually increasing length of span, the use of more slender and graceful piers, the reduction in thickness of the arch ring consequent upon a better knowledge of the mechanics of the arch, and the increased beauty of proportion and adornment. Progress, too, was made in the methods of foundation, by the use of caissons, dredges, mechanical pile drivers and saws for cutting off piles under water.

In the present century, and especially since the birth of the rail-

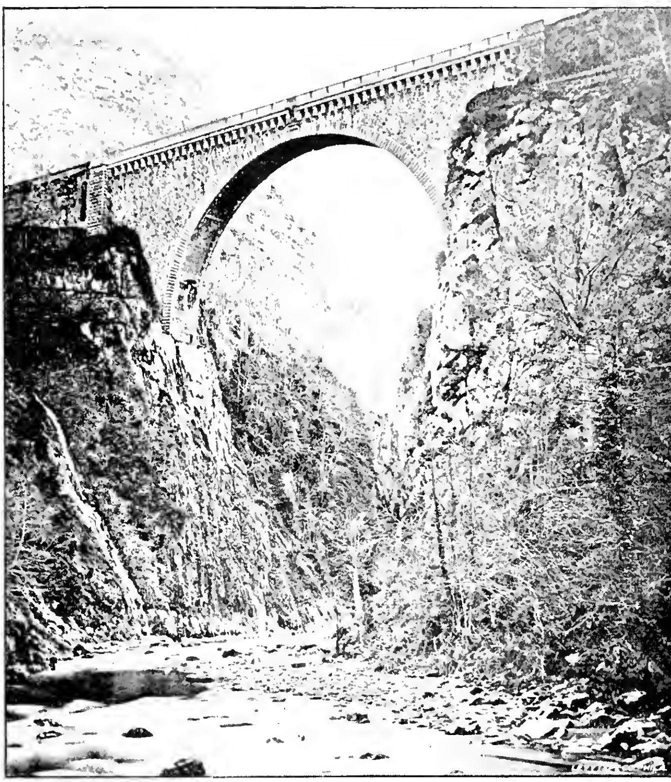

FIG. 21.—BRIDGE OF ST. SAUVEUR.

road in 1830, a great many stone bridges have been constructed, but the types have not changed, and the development has simply been in the directions just indicated.

Figs. 19–20 show some modern bridges. Fig. 19 is the Pont Neuf at Albi, in France, an extremely light and graceful structure. Fig. 20 is the Nydeck bridge at Berne, with a span of about 148 feet, a fine structure. Fig. 21 is the Pont St. Sauveur, in the Maritime Alps, with a

span of 140 feet, and a height of 215 feet above the river. Fig. 22 is a view of two bridges, the older having steep approaches and a small width, to remedy which a modern bridge has been built alongside, nearly level, and of sufficient width for the increased traffic; Fig. 23 is the "Viaduc de Morlaux," and Fig. 24 is the famous Roquefavour aqueduct, in France, the highest stone bridge in the world.

These views show that there is no very great or essential difference between stone bridges of the present day and those of the Romans. There are differences in detail, with regard to the shape of the curve of the arch, the arrangement of the stones, the bonding,

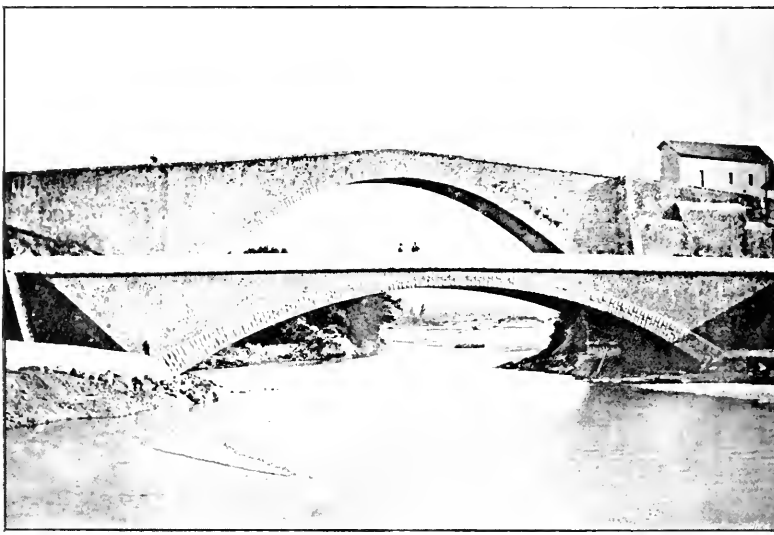

FIG. 22.—ANCIENT AND MODERN FRENCH BRIDGES.

the proportions of the piers, etc.; but the general principle and construction remain the same.

In America there are few large stone bridges. This is but natural in a new country. Not strange is it, either, that most of our large stone bridges are on works of water supply rather than on railroads. Our country has been built up by the railroads, which have penetrated in advance of civilization into new regions, and have been too poor at the beginning to build such costly structures—unlike the railroads of Europe, which were built through already rich and populous districts. Aqueducts, on the other hand, are built to supply already wealthy and populous cities, and the most durable and expensive structures are justified.

Of railroad bridges there are but very few large structures. The

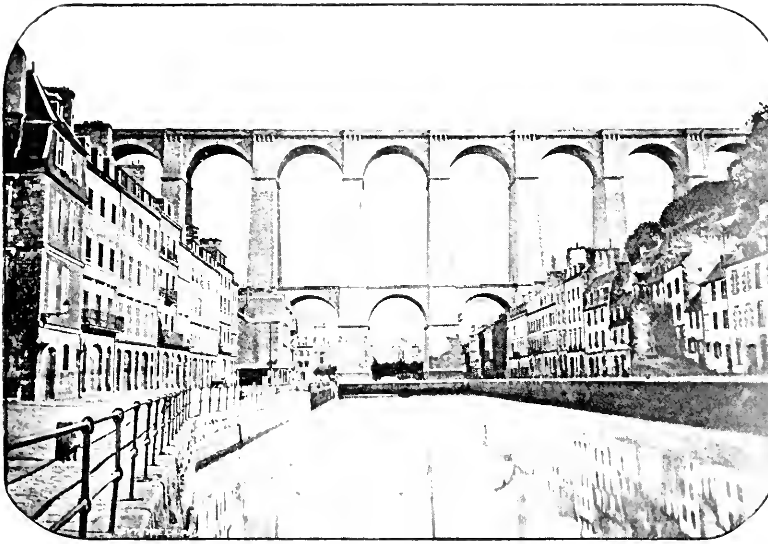

FIG. 23.—VIADUCT OF MORLAUX, FRANCE.

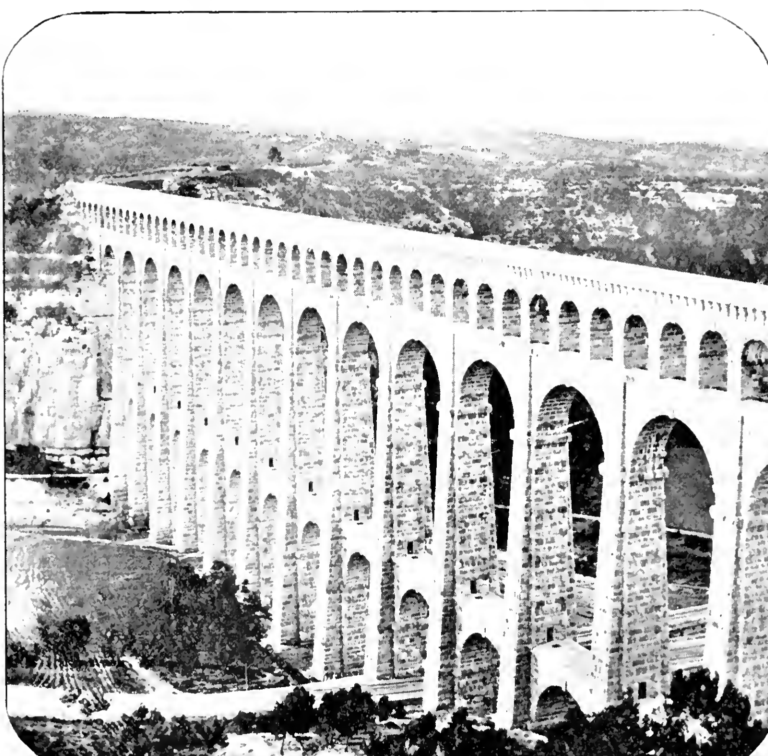

FIG. 24.—ROQUEFAVOUR AQUEDUCT, FRANCE.

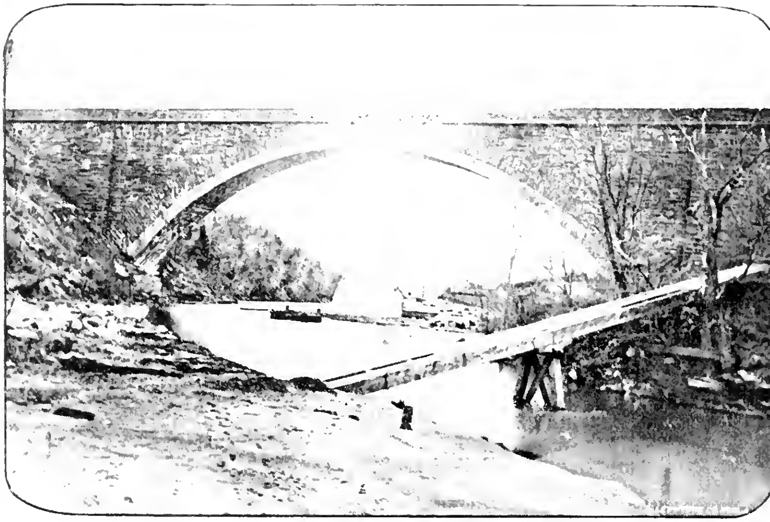

Fig. 25.—Cabin John Bridge, near Washington, D.C.

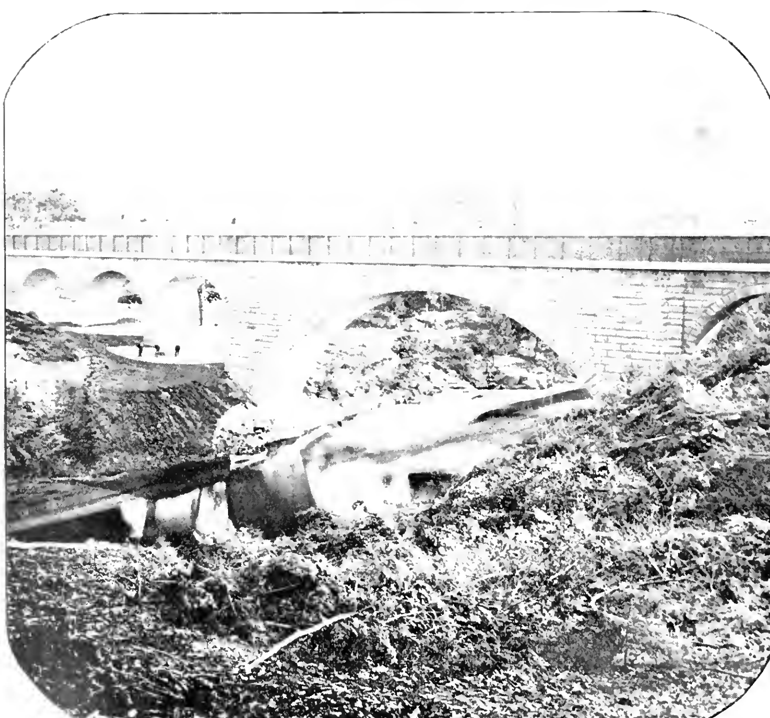

Fig. 26.—Echo Bridge; Sudbury Aqueduct, near Boston, Mass.

earliest was the Thomas viaduct, between Baltimore and Washington, over the Patapsco River, with eight elliptical arches on a curve. The spans are 58 feet, and the height above the river 65 feet.

The next is the Starucca viaduct, on the Erie road, in northern Pennsylvania, with eighteen arches of 50 feet span and 110 feet high.

A third is the Canton viaduct, on the Boston & Providence Road.

All of these, however, compared with the structures which have just been described, are unimportant works.

Of aqueducts, the first is High bridge, over the Harlem River, in the old New York aqueduct, with seven spans of 50 feet and eight spans of 80 feet, the height above the water being about 100 feet.

The second is the Cabin John bridge (Fig. 25), over the creek of the same name, in the aqueduct supplying Washington. This was built by Gen. Meigs in 1866, and has one segmental span of 220 feet, with a rise of 57 feet 3 inches, being the largest stone arch span in existence, and only exceeded in the world's history in the case of the bridge at Trezzo, already mentioned. This bridge is but 20 feet wide.

The third is the Echo bridge (Fig. 26), on the Sudbury River aqueduct, supplying Boston. This has a span of 127 feet and a rise of 42 feet.

(The lecture, of which this is a portion, was illustrated by a great many views, which space will not permit us to insert, showing most of the bridges referred to in the text, and many others not specifically described.)

Bradley & Poates, Engr's, N.Y.

ASSOCIATION
OF
ENGINEERING SOCIETIES.

Organized 1881.

JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, 1896.

Errata in November number, page 146, lines 21, 22. For June and December read March and September; for March and September read June and December.

It would be of advantage if all our courses could be noted with reference to the true meridian, but the labor required to run them so has heretofore been such that the cost has seemed to outweigh the benefits.

The purpose in making all original surveys should be to so do our work that it can at any later time be reproduced with the least possible labor and the highest degree of accuracy. If monuments are placed to mark every line, there will be no future uncertainty so long as the monuments remain. If increased facilities for finding the true meridian shall tempt surveyors to neglect setting monuments, then by so much will those facilities work harm.

One of our members, Mr. John B. Davis, has devised and patented an instrument for determining the meridian by a method which, he claims, not only reduces the labor but also increases the accuracy of the work.

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* Manuscript received November 4, 1896.—*Secretary, Ass'n of Eng. Socs.*

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SOLAR WORK IN LAND SURVEYING.

A Statement of the Principles Involved and an Exhibition of a New Solar Device.

BY J. D. VARNEY, MEMBER OF THE CIVIL ENGINEERS' CLUB OF CLEVELAND.

[Read before the Club, October 13, 1896.*]

IT appears that descriptions of land lines by courses and distances, such as we now use, are found in the cuneiform writings of Babylonian relics. The long use of that form is not proof that it is best, but that it is the best is, I believe, the reason that it has been used so long. Wherever another form appears on our records, it impresses us as being an exhibition of pedantry.

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* Manuscript received November 4, 1896.—*Secretary, Ass'n of Eng. Socs.*

It is the purpose of this paper to introduce to you one of his instruments which was manufactured for me by Messrs. Ulmer & Hoff of this city, and to give a correct idea of its construction requires that I should describe the principles involved.

The earth is revolving around the sun at a distance of about 93,000,000 miles. The plane in which it revolves is called the plane of the ecliptic. The earth is revolving also on its axis, causing the phenomenon of day and night.

This axis or line passing through the center of gravity and around which it revolves daily is not perpendicular to the plane of the ecliptic, but is inclined about 23½° from the perpendicular. For the purposes here treated, this angle may be regarded as constant, and the position of this axis at any given time, as therefore parallel with its position at any other given time. The equator is an imaginary line passing around the earth midway between the poles. As the axis is necessarily at right angles to the plane of the equator, it follows that the planes of the equator and of the ecliptic are at the same constant angle as the angle of the axis to the perpendicular. From these facts it follows that, as the earth revolves around the sun, there are two positions in which the sun is in both planes, those of the ecliptic and the equator. These occur in June and December. Then the sun appears to travel alternately north and south until, in March and September, its angular distance from the equatorial plane is equal to the angle between the planes of the ecliptic and the equator. This angular distance of the sun from the equatorial plane at any specified time is called the declination of the sun for that time.

The lines of which we as land surveyors treat are not lines, they are planes. The center of the earth is a point in each of them and they extend indefinitely upward. We treat of them as extending far enough vertically to include the points of which we speak as being in line. When we speak of three points as being in line, we mean that the center of the earth is a fourth point in the same plane as the three given points.

The meridian of any point is a plane passing through that point and through the earth's axis. The whole problem in this inquiry is: From a given point in the earth's surface, to find another point in that surface which shall be in the same meridian plane, and to do this by observations of the sun.

If a circle of the size of the earth's circumference could be marked around the center of the sun so that we could use it as a target, it would be about like using a target 1 inch in diameter at a distance of 1000 feet. Whether the line of sight is directed to the side or to the center of such a target makes an angular difference of about 9 seconds. As affecting solar work, this parallax would be produced only at one of the poles of

the earth, and, as we are not likely to go there to do solar work, and as, in all lower latitudes, the angle would be less, we may ignore it and treat all the angles we use as if made at the center of the earth, from which point, I understand, astronomical calculations are usually made.

Let us suppose the earth to be so placed that its axis is perpendicular to, and that its equatorial plane coincides with the plane of the ecliptic, and that our point of observation is on the equator in the "sun-rise" position. By "sun-rise" position, I mean that position in which a plane tangent to the earth's surface will strike the center of the sun, subject of course to a parallax error.

If the conditions are plainly pictured, it will be seen that if with an ordinary transit we should turn 90° from the sun, we would bring the optical axis of the telescope in the meridian plane, and our given problem would be solved.

With a line given, and another line to be determined by turning a given angle from a given point in the given line, there are two methods by which we can turn that angle.

For the sake of brevity I will, for the present, discuss only right-angles, assuming that the modifications for other angles are so obvious as to require no special description.

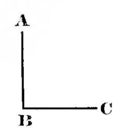


FIG. 1.

Having the line A B (Fig. 1) given and wishing to find the line B C which is known to be perpendicular to A B from B, the usual method is as follows: Set up and level the ins.rument over B; set the zeros; direct the line of sight to A, using the lower movement; turn the upper plate 90°, and the line of sight will then necessarily be in the vertical plane B C.

The mechanism used in all solar work which will here be considered is such that two lines of sight are so attached that they can be set and clamped at any desired angle to one another. Assume that we have such an instrument placed over B with the lines of sight clamped at right-angles to each other. Obviously, if one is in the vertical plane A B, the other must be in the vertical plane B C.

If, for the lines of sight we use telescopes, if, to one of them, we attach a reflector clamped at 45° to its optical axis, and if we so place the instrument that the point where the optical axis of the telescope strikes the reflector is in the vertical line passing through B, the image of A can be brought into the optical axis, when, and only when, that optical axis is in the vertical plane B C.

Taking advantage of this well-known law of optics, one telescope is made to suffice instead of two. This is the method of the Davis Solar.

We are now to describe Mr. Davis' method of fixing this reflector at right-angles vertically and at the required horizontal angle to the optical axis.

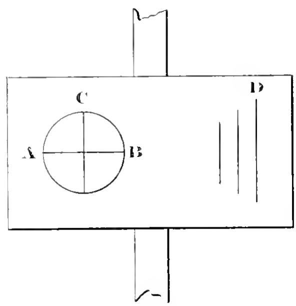


Fig. 2.

A target is required and Fig. 2 represents the form used. The line *A B* is to be made horizontal. The other lines are perpendicular to *A B*. *D* is to be used when the reflector is to be set at 45° for right-angles. The distance between the lines *C* and *D* is equal to the distance from the transit axis of the telescope to the axis of the reflector. The remaining lines are for other than right-angles, and are at distances from the line *C* equal to the sine of the required angle multiplied by the distance *C D*.

Assume that we have a transit such as is used in ordinary survey work, with level on telescope, and clamp and tangent movement on the vertical axis. Set it at random. Level the plates and telescope. Set the zeros of the limb. Have the target placed at a convenient distance, with its face at right-angles to the line from the instrument. Have it raised or lowered until the line *A B* is covered by the horizontal hair. With the lower screw fix the vertical hair on *D*. Turn 90° to the left. In place of the sun-shade, fix this reflector attachment, which consists of a ring fitting around the object glass, close enough to have no lost motion and loose enough to be turned easily. By an upper and lower bar a plane reflector is attached to this ring, a short distance from the object glass. Being supported by pivots, this reflector revolves on its axis at or near its middle line. We revolve it by the ring to make it vertical, and on its pivots to bring it to the required angle—until the vertical hair covers the line *C* of the target, and the horizontal hair covers the line *A B*. When this occurs, we know that the face of the reflector is at right-angles vertically and at 45° horizontally to the optical axis of the telescope.

In this position let us clamp it and take it with us to our assumed "sun-rise" position on the equator.

Do not forget that the plane of the equator is now assumed to coincide with the plane of the ecliptic.

Level all the parts. This being done, the optical axis will revolve in a plane tangent to the equator, when the telescope is revolved by the plates. The sun is in that plane.

By revolving the plates, bring the image of the sun on the cross of the hairs. The optical axis will necessarily be in the meridian plane, and again our problem is solved.

Clamp all the parts in this position and leave it while we introduce another modification of the engineer's transit, made necessary by the fact that we cannot make all our observations at sunrise.

In place of being rigidly fixed in its transit axis, the telescope is placed in a sleeve in which it can easily be revolved on its optical axis as level telescopes are revolved in their Ys. As it is this sleeve, and its relation to the reflector, that constitute the departure of this from all other devices, it is important that for a time I digress from the discussion of astronomical conditions and speak more fully of this mechanical construction.

The object glass is fixed, hence all focusing is at the eye end of the telescope. The reflector is so attached at the object end that when, by the slow motion screws, it has been placed in the relation to the optical axis required for any specific observation, it can be clamped and held in that relation as if it had been constructively made for that observation and for that only. When the telescope is revolved in the sleeve, the rays of light which are reflected into the optical axis form a plane perpendicular to the optical axis if the angle is 45°. If not, they form the surface of a cone, the apex of which is in the optical axis and at the point where it meets the surface of the reflector.

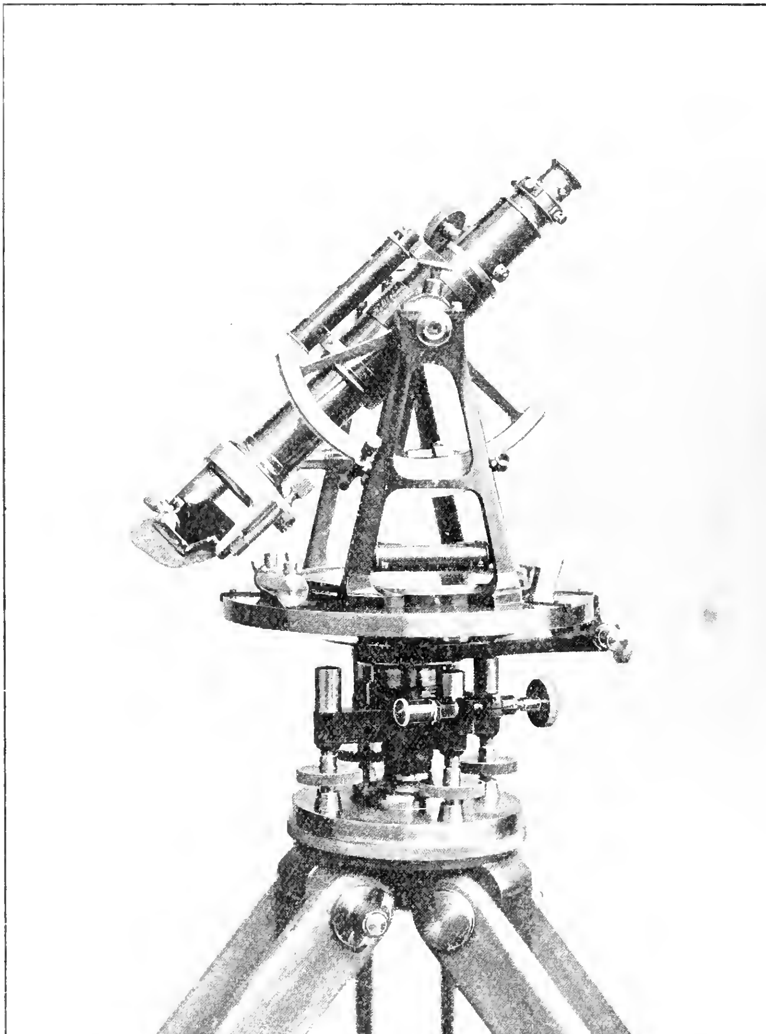
This device is not new in all its parts. Reflectors have been used and they have been attached to a ring on the object end of the telescope to serve the purpose of the hour arc. Usually they have been set by graduated arcs and verniers. Others have a stationary object glass. All exclusively leveling instruments revolve on the optical axis in the Ys. All former devices have, however, required adjustment. The combination made by attaching the reflector to the fixed object end, setting it by means of the graduated limb of the transit, and then, by means of the sleeve, revolving the telescope on its optical axis, and, by means of these, eliminating all adjustments which are not required for other transit work, is the crowning feature of this device.

Setting the reflector by using the target is not an adjustment, but by so setting it, results are obtained which in all former devices have required three or more delicate adjustments. All the usual adjustments of the transit must be carefully made, but that is required if any other work is to be well done.

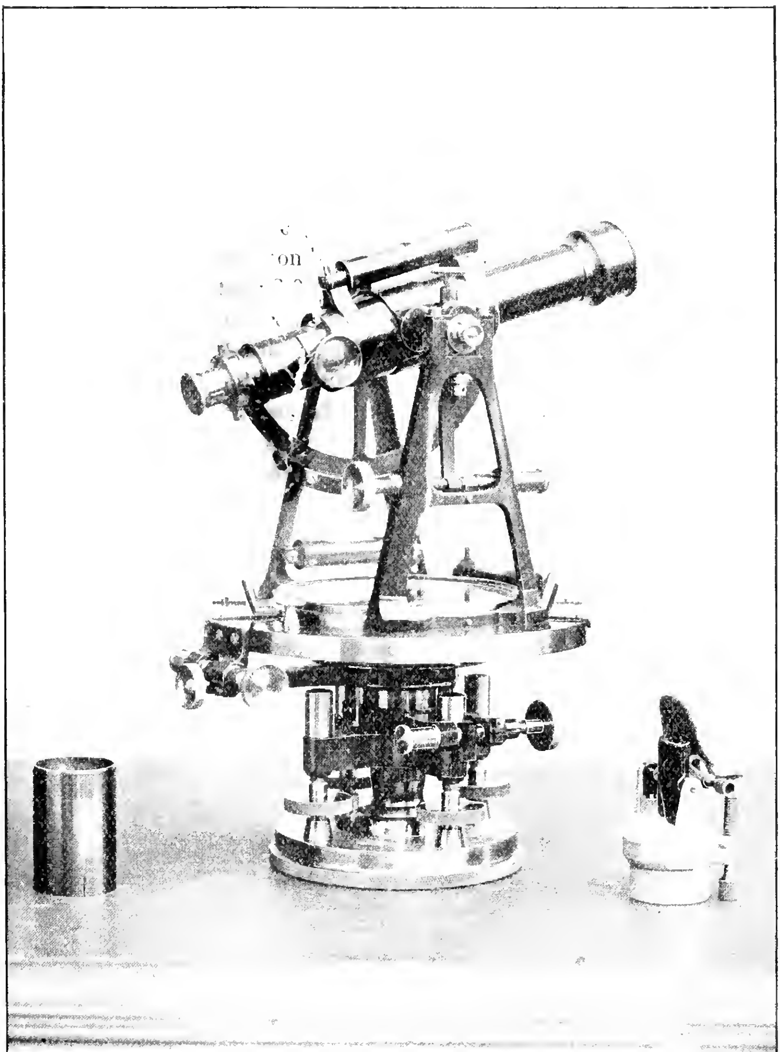
Remove this reflector and we have simply an engineer's transit improved by the fact that the sleeve enables us to adjust the line of colimation by sight in one direction as in Ys.

Going back we now place this sleeve modification in our mental picture of the clamped instrument which we left standing on the equator. The optical axis was left on the meridian plane. The light of the center of the sun was thrown by the reflector on the cross of the hairs.

Keeping the instrument and all its parts stationary with reference to the earth, let us leave it for some definite length of time, say two hours, in which time the earth will have turned on its axis 30°. The



J. B. Davis Solar Transit. Reflector Attached and Instrument Ready for Observation.



J. B. Davis Solar Transit. Reflector Detached.

appearance, to us, will be that the reflector is still directed to the "sun-rise" position, but that the sun is two hours high.

It will, however, be seen that if we had turned the telescope in the sleeve with the same angular velocity with which the earth turned on its axis, that is, 15° per hour, and without changing the optical axis from its position parallel with the earth's axis, the vertical hair would have continued to bisect the image of the sun during the whole movement.

If now we turn the telescope in the sleeve 30°, so as to bring the image of the center of the sun on the cross of the hairs, the optical axis of the telescope will have remained in the meridian plane, but the vertical hair will stand at 30° to that plane. If, again, we wish to mark a point in that plane, we have only to turn back the telescope in the sleeve until the vertical hair is vertical, remove the reflector and proceed in the usual way. So much for the method in the "sun-rise" position.

Let us now commence an observation on the equator at some other time than sunrise, the assumption continuing that the planes of the equator and the ecliptic coincide. So far as concerns this observation, the time may be unknown, except that, for reasons to be hereafter given, it must not be at noon and for the most reliable work it should be between 8.00 and 10.00 A.M. or between 2.00 and 4.00 P.M.

Please do not forget the assumption that the plane of the equator coincides with the plane of the ecliptic.

Level all parts of the instrument. Using the target in the manner before described, set the reflector at the required angle, 90°. Revolve the telescope horizontally by one of the plates and on its optical axis in the sleeve until the image of the sun is bisected by the vertical hair. If the conditions are clearly pictured, it will be seen that this can only occur when the optical axis of the telescope is in the meridian plane, but the vertical hair will be at an angle to the vertical or meridian plane equal to the angular distance of the sun from the "sun rise" position. To mark out the meridian, we must turn the telescope in the sleeve until the vertical hair is vertical, remove the reflector and proceed in the usual way to mark the line, and again our problem is solved.

Because some mental effort on my part was required to see why solar observations near noon are unreliable, and at noon, valueless, I may be pardoned for giving some time to that subject. Keep in mind our position on the equator, the plane of which is assumed to coincide with the plane of the ecliptic; also keep in mind that the lines under discussion are not simply lines, but sections of planes.

The name noon is given to the time when the sun is in our meridian plane. Hence to direct the telescope to the sun at noon we must place the optical axis vertical. In that position no angle can be measured

because to revolve the upper plate is only to revolve the optical axis on itself.

To illustrate further. Place the instrument over *B* (Fig. 1), to observe the angle *A B C*, which, for this purpose, may be more or less than 90°. Turning from *A*, we usually look, not at the actual monument *C*, but at a flag-pole placed in the vertical plane *B C*. Let us assume this flag-pole to be in the form of a curve, the center of which is at the instrument. From *B* we may observe the angle *A B C*, turning from *A* to successive points on the flag-pole above the horizontal, but as we approach the perpendicular our work will be less and less reliable, until at the perpendicular, we simply turn the telescope on its optical axis. When the telescope is elevated 60° from the horizontal, or 30° from the vertical, the conditions are practically the same as those of solar work at 10.00 A.M. or 2.00 P.M.

Let us now inquire as to the modifications necessitated by the fact that the planes of the equator and the ecliptic do not coincide. To simplify our conception, let us eliminate the reflector and assume that we turn angles in the usual way. Let us go back to our assumed "sun-rise" position on the equator, the plane of which is still assumed to coincide with that of the ecliptic. By leveling up, we make the plates and the telescope tangent to the earth. Bisect the image of the sun with the vertical hair. Taking parallax into account, the horizontal hair will be above or west of the center of the sun a distance equal to the semi-diameter of the earth. Picture a line passing through the centers of the sun and earth and indefinitely extended. Coming from the sun it would strike the earth 90° east of us and pass out 90° west from us. On this line as an axis let the earth revolve. This being clearly pictured, it will be seen that this revolution might be continued indefinitely and that the cross hairs would appear to remain fixed on the center of the sun.

Taking parallax into account, and imagining the optical axis of the telescope to be a pencil extending to the sun, and the sun to be a sheet of paper, the pencil, as the earth revolved, would describe around the center of the sun a circle of the size of the earth, and at all times the vertical hair would cover the center of the sun.

By our terms, adopted at the outset, we have placed the telescope at right angles to the meridiam by directing it to the sun. By our terms the position of the telescope remains fixed with reference to the earth. Therefore, at any point in the supposed revolution, we should find the meridian by turning 90° from the sun. In other words, at that time in March and September when the sun is in the equatorial plane, we should find the meridian by turning 90° from the sun.

Let us again return to our assumed "sun-rise" position, with the planes of the equator and the ecliptic coinciding, with all parts of the

instrument leveled and with the telescope directed to the center of the sun.

Imagine a line passing through the instrument and through the center of the earth and indefinitely extended. On this line as an axis let the earth revolve, the north pole moving toward the sun an angular distance equal to that between the planes of the equator and the ecliptic. By that movement we should have, so far as this inquiry is concerned, the same effects as are produced by the movements of the earth around the sun from March to June. By reversing the direction we should have the effects witnessed from June to December.

Let us now go back and assume the north pole to have moved some definite distance, say 10°, toward the sun. If this is clearly pictured, it will be seen that the line of sight will have left the sun and will now be directed 10° south of it. The meridian will, by our terms, still be at right angles to the telescope. We would, therefore, turn 90° minus 10° (= 80°) from the sun for a north line, or 90° plus 10° (= 100°) from it for a south line.

This angle, taken here as 10°, being the declination of the sun, its value for any hour or minute of each year can be easily determined from data given us by the astronomers, and it is with reference to this only that the time in the day or even in the year becomes a factor in solar work. I make this statement because of the possibility that some others may have the same erroneous conception that I had until recently. Because I was told that a man, engaged in solar work, must carry a watch to know the time of day, I assumed that it was in some way, I did not know how, connected with the 15° per hour that the earth turns on its axis. This would require an accurate timepiece, whereas a fairly good "Waterbury" will do.

Thus far, our observations have been made on the equator. But we are actually in latitude about 41° 30′ north. Our plumb bobs point to the center of the earth and are not perpendicular to its axis. Our level bubbles, keeping as far as possible from coinciding with the plumb lines, assume positions at right angles to them.

If we could but have such a modification of the laws of gravity that the plumb lines would hang at right angles to the earth's axis, instead of tending toward the center of the earth and that the level bubbles would continue to assume positions at right angles to the plumb line, our work would be simplified and we could do our work on any part of the earth's surface in the same manner as at the equator. As it would be difficult to pass such an amendment to the laws of gravitation, we may as well submit and make the necessary amendments to our transit. This is very simple, after all, requiring only the addition of a vertical arc, with which we are all familiar, to the axis of the telescope.

Knowing the latitude, we know also the angle between the axis of the earth and a horizontal plane. We find a horizontal plane by leveling the plates and the telescope. We elevate the object end of the telescope if we are to look north, or depress it if we are to look south, until the vernier of the vertical arc indicates the correct angle. We then proceed, in all other respects, as if we were on the equator.

It has thus far been assumed that the latitude is known. It now remains to *find* the latitude when it is *not* known. This must be done with as high a degree of accuracy as possible, because errors here are repeated and sometimes multiplied in our results. One thousand feet north or south makes a difference in latitude of between nine and ten seconds.

We must know the declination of the sun at noon of the day on which we are to find the latitude. As this is learned by other means than the use of this instrument, the knowledge of it is assumed. For example let us assume it to be 10° north. It is more convenient to depress the object end than the eye end of the telescope, this instrument is therefore constructed to look south, and the angle we are to deal with is the same as that which we should use if the latitude were known and we were about to find the meridian, that is, 90° + 10° = 100°.

We go back and follow the instructions for fixing the reflector in position, except that in place of turning off 90°, as then described, we now turn off 100°. This work should be completed some time before noon.

That the plates and telescope are made level is provided for in fixing the reflector. We now set the zeros of the vertical arc and clamp it to the telescope while that is yet horizontal. Loosen the vertical clamp of the telescope. Loosen one of the plates; whether the lower or upper one, is not important. Turn the object end southerly. Turn the telescope in the sleeve so that the vertical hair will be horizontal. Revolve the telescope by the plates and elevate or depress the object end until the vertical hair, now made horizontal, bisects the image of the sun. Keep it there, following the sun by using the slow motion screws when necessary until the greatest elevation of the sun is reached. Before it recedes, read off the angle indicated on the vertical arc. This will be the latitude of the place.

The optical axis of the telescope will then be near the meridian, but we must not assume that it is in the meridian. If in the meridian, it would be parallel to the earth's axis.

I have spoken of the "sunrise" position, assuming that the modifications necessary in applying the discussion to sunset are too obvious to need statement.

I have said that we cannot make all of our observations at sunrise.

In fact, on account of refraction, it is not practicable to make any of them at either sunrise or sunset. Your knowledge of the nature and extent of this factor is assumed.

Accompanying the tables of declination, the astronomers have given us data for correction for refraction.

Between refraction near sunrise and sunset, and the heretofore mentioned inaccuracy near noon, the time favorable for observations is limited to a few hours daily. It has been found that the best results are obtained between 8.00 and 10.00 A.M., and 2.00 and 4.00 P.M.

My efforts for brevity necessitate some further explanations. We do not attempt to bisect the image of the sun with a single hair, but bring its image under two hairs which cover a space a little less than its diameter.

The reflector is made vertical, not actually by turning it on the object glass as intimated, but by a better device, with which, however, it would have been difficult to describe the principles involved.

I have spoken of removing the reflector to mark the points in the meridian. This is not necessary, because, if it is so turned that it is in or near the line of the optical axis, it ceases to be an obstruction to vision. It can, however, be easily removed, and is kept on the telescope only when solar work is to be performed.

As in other astronomical work, an inverting eye-piece is used. This is not a necessity, but by its use mechanical difficulties are more easily overcome and, personally, I prefer it for ordinary transit work.

By a simple though not easily described device, the revolution of the telescope in the sleeve is arrested when the vertical hair is vertical.

A shaded glass is used at the eye end to enable us to look at the bright sun.

Persons familiar with other solar instruments will observe that the limb of the ordinary transit is here used as the declination arc.

Since this instrument was finished there has been but one day available for solar work, and on that day there was available time only for two observations. One was made by Mr. Davis, and the other by an observer who was unfamiliar with the work. On a meridian previously established, one struck 15 seconds east and the other 15 seconds west.

Mr. Davis, who has used (since July, 1895) the first instrument made, says that his maximum error is 30 seconds.

In conclusion, I feel that it is no more than is due to Messrs. Ulmer & Hoff that I be allowed to say that the workmanship of the entire instrument is as near perfection as that of any instrument I ever examined. More than this, an examination will show that they have made minor improvements to the instrument as a transit, which show that every step in its construction has been thoroughly, conscientiously, and scientifically thought out.

BOILER EFFICIENCY, CAPACITY, AND SMOKELESSNESS, WITH LOW-GRADE FUELS.

By William H. Bryan, Member of the Engineers' Club of St. Louis.

[Read before the Club, October 21, 1896.*]

Probably the most interesting question now before the mechanical engineers of this country is the proper method of expressing the efficiency, or economy, of steam boilers, and with this is closely connected the entire subject of the methods of making evaporative trials.

Active discussion of the matter was precipitated at the Detroit meeting of the American Society of Mechanical Engineers in 1895, when a paper by Mr. F. W. Dean, of Boston, on "The Efficiency of Boilers, a Criticism of the Society's Standard Code of Reporting Boiler Trials," was read. Mr. Dean not only recommended a complete revision of this code, but took strong ground in favor of determining and reporting, in every boiler trial, the heat value of the fuel used, and comparing that figure with the actual heat utilized in doing useful work in the boilers.

The discussion which followed the reading of this paper was interesting and extensive, and it continues unabated to the present day, as is indicated by papers presented at both meetings of the Society since that date and by correspondence in the technical journals. As a result of Mr. Dean's paper, the Council of the American Society of Mechanical Engineers appointed a committee to consider the standard method of 1886 of conducting steam boiler trials, and to recommend to the Society such revision of that standard as might seem desirable to them. The committee appointed consists of Messrs. Geo. H. Barrus, J. S. Coon, F. W. Dean, Chas. E. Emery, Wm. Kent, R. W. Hunt, C. T. Porter, Prof. W. B. Potter of this city, and Dr. R. H. Thurston. This committee is now engaged on the work entrusted to it, but it having proved to be an undertaking of great magnitude, involving the consideration of many intricate problems, there is no telling when their report will be presented to the Society.

It is generally conceded that the Society's code needs revision. At the time of its preparation it represented the best practice, and the fact that it has stood until now without material modification, or even serious criticism, is the best compliment that can be paid its authors. At that time, however, boiler trials were only rarely made, and the

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methods and apparatus had been but imperfectly developed. In fact, the entire theory of boiler performance was but imperfectly understood. Since then the making of boiler trials has become general, many thousands of them having been made, and they are now matters of almost daily occurrence, particularly in the larger cities. It is not surprising therefore, that the great development of this branch of engineering, should have brought to light some features which were not considered at the time the present code was prepared. For these reasons the code should now be so modified as to bring it into harmony with the best practice of the present day.

Perhaps the most important question involved in this revision is as to the best method of expressing the economic performance of a boiler. Broadly speaking, boiler efficiency means the ratio between the work done by the boiler and the fuel expended per unit of such work; or, to put it more precisely, the ratio between the heat realized in useful work by the boiler and that existing in the coal which the owner has paid for.

Until recently the economic performance of a boiler has always been expressed in the number of pounds of water evaporated for each pound of fuel burned, and for each pound combustible; the latter term meaning simply the remainder after deducting from the total coal burned the pounds of ash weighed back. There being wide variations between the temperatures of the feed water, and the pressures carried at different trials, the above results were always reduced to the "equivalent evaporation from and at 212," which is what the boiler would have done had the temperature of the feed water been 212°, and the water evaporated at the same temperature, or at atmospheric pressure. This enables comparisons to be made between different trials under different conditions of feed and pressures.

For some years past many engineers have believed that the efficiency thus stated did not tell the whole story. The "equivalent evaporation per pound of coal" is meaningless, unless we know all about the coal. The situation is not much improved by reducing it to the "pound combustible," as this latter term is easily liable to error, particularly with low-grade fuels running high in ash, and making bad clinkers, such as are almost universally employed in this part of the country. These engineers strongly urged that in every boiler trial the coal burned be carefully sampled, and immediately submitted to chemical analysis and calorific determination. The report of results should show these facts as well as the theoretical evaporative power or capacity of a pound of coal. Comparing this with the work actually done by a pound of the coal, the efficiency percentage is at once secured. In the opinion of many engineers, this figure is, everything considered, much the best method of expressing the economic performance of a boiler.

Much to our surprise, the agitation of this subject has developed remonstrances and from quite unexpected sources. Some of the most noted engineers of this country, supposedly most familiar with boiler trials, have taken the position that the efficiency thus determined and stated would in no way improve the situation, and might, indeed, be misleading. These engineers do not seriously defend the "pound combustible"—in fact, they practically admit all that has been urged against it. Their sole ground of objection is the belief that the science of coal calorimetry has not yet reached such a point that implicit confidence can be placed in the results.

Eastern engineers, whose work is almost wholly with high-grade coals running very low in ash, have not experienced the trouble with the "pound combustible" that we have. Very few Western engineers share with them the lack of confidence in calorimeters. My own files contain more than one hundred such determinations, made with all sorts of fuels, under all sorts of conditions, among them many different investigations of the same fuel at different times. The results show a consistency which cannot help inspiring confidence in the methods. Even if we admit that the coal calorimeters are not all they might be, the extended experiments which are now being made in this direction, and the resulting constant improvement in apparatus, must certainly bring about in the very near future—if they have not already done so—methods and apparatus which will meet every requirement.

While I am a hearty believer in the efficiency, as determined by the more modern methods, I believe nevertheless that the results per pound of coal and of combustible—both actual and equivalent—should be given in all reports, if for no other reasons than that everybody expects them, and that a report would hardly be considered complete without them. I am always very careful to state in addition, however, the efficiency in percentage realized of the calorific value of the fuel. It is then entirely a matter of choice as to which of these expressions the individual reader will give the most weight.

The modern steam boiler is a creditable piece of engineering. Its uses are almost without limit, the most important being the heating of buildings, the generation of steam for steam engines, cooking, boiling and making distilled water for ice manufacture, etc.

The pressures carried regularly vary almost as much, being from 0 to 10 pounds per square inch for heating, from 70 to 100 for ordinary service, 125 to 150 for compound or compound condensing engines, and from 175 to 200 on steamboats and locomotives, and where high-duty triple or quadruple expansion condensing engines are employed.

The performance of a boiler may be measured in many different ways:

A. By the capacity developed ordinarily and as a maximum.

B. By its fuel economy, under all the varying conditions of service.

C. By the dryness of the steam which it generates.

D. By the smokelessness of its performance, a condition which is of decided importance in large cities, and which depends as much on the particular setting or furnace employed as upon the boiler itself, if not more.

Evaporative trials are made to determine all the above features. They are also made to secure information on any of the following questions:

A. The value of the different fuels, to ascertain what grade of fuel will evaporate the most water for a dollar. In such trials all conditions must be kept as nearly constant as possible.

B. To determine the effect of different fuels, not only on the cost of doing the work, but also on the capacity, durability and smokelessness of the plant and on the labor required to handle it.

C. To determine the relative efficiencies of different types of boilers, particularly of new and untried designs.

D. To secure the same information regarding different furnaces, stokers or grates, all as applied to the same boiler; it being necessary to determine not only the difference of economy of the fuel, but also the effect of the changed conditions on the capacity, labor, smokelessness and durability of the plant.

E. To determine the effect of different conditions of operation, such as greater or less draft, mechanical draft, either forced or induced; different methods of firing; different conditions of the boiler as to cleanliness; different rates of evaporation, to determine the point at which the fuel economy is a maximum, and the extent to which the boiler can safely be crowded in emergencies.

The most common necessity for boiler trials arises from boiler contracts which include specific guarantees of performance. When boiler or furnace manufacturers make large claims for economy, it is natural that the purchaser should embody those claims in the contract, and require a demonstration of them before accepting and paying for the plant.

Scientific and accurate determination of boiler performance has of late years received an impetus from the growing practice of paying for boilers on the basis of their economic performance. Every additional pound of water evaporated per pound of fuel burned, means a noteworthy saving in annual operating expenses, which saving can be reduced to dollars and capitalized, thus furnishing a measure of the increased investment, which the purchaser can afford to make in the first cost of a boiler of more economical type. When this plan is

followed, bids for boilers are asked for on some assumed basis of efficiency, frequently 65 per cent. to 70 per cent. After the boilers are ready for service, they are to be tested thoroughly by disinterested experts, and the contractor is paid a bonus on each boiler for every 1 per cent. which is realized over and above the stipulated basis. In case the results fail to reach the basis, then the contractor suffers a deduction for each 1 per cent., the amount being either the same as for the bonus, or greater.

When bidders make up their proposals in a case of this kind, they are supposed to know exactly what efficiency their boilers will develop under the conditions set forth in the specifications; or, if they do not know, they must ascertain. Having completed their estimate of the cost of the boiler, and decided upon a figure which they must realize for the installation, they either add to or deduct from that figure a sum depending upon the efficiency which can be secured. Suppose, for instance, a builder desires to realize $3,000 per boiler on a proposed installation, on which the efficiency demanded is 70 per cent., and a bonus of $250 is to be paid for each 1 per cent. above that point, and the same amount deducted if the basis is not reached. If the bidder is certain he can reach 75 per cent. he would be sure of a bonus of $1,250 on each boiler, and could safely reduce his bid by that amount, offering the boilers for $1,750 each.

The recent bidding for the new boilers of the Baden Pumping Station of this city is a prominent example of this method of procedure, the bids being about one-third lower than the same boilers could usually be purchased for in open market, the contractors nevertheless expecting in the end to realize the full selling price, or more. This method makes it to the contractor's interest to build a plant which represents the very highest improvements in economic performance, and should insure to the purchaser a plant which can be operated for the minimum expenditure for fuel.

The following table is an abstract of the results of a number of boiler trials made by the writer on the conditions and fuels common in this vicinity, nearly all of them being made on ordinary Illinois fuels. They represent the widest extremes of practice, including many badly designed and overworked boilers:

Kind of Boilers.	Number of Trials.	EFFICIENCY—PER CENT. Maximum.	Minimum.	Average.
Small vertical	3	46.10	34.60	41.60
Large "	3	52.30	49.00	50.90
" improved setting . .	1	. . . . . .	One trial only	67.89
Tubular boilers	14	60.17	44.76	51.53
" improved setting	34	76.38	41.94	58.87
Water tubular	13	70.11	49.37	61.31
" improved setting .	18	81.32	49.30	67.52
		SMOKE EMITTED—PER CENT.		
Common furnaces	7	75.42	11.09	46.52
Improved "	40	43.40	.29	9.45

The figures are quite interesting, indicating, among other things, that the best improved furnaces increase the efficiency over 25 per cent. above the best common setting under a tubular boiler, and about 15 per cent. under a water tubular boiler. The average daily results of the plants taken just as we find them, show that the improved furnace improves the efficiency of the tubular boiler about 15 per cent. and that of the water tubular about 10 per cent. The best water tubular boiler does over 15 per cent. better than the best tubular with ordinary setting, the increase, however, under average conditions being about 20 per cent. It is interesting to note that the *minimum* efficiency secured, both with tubular and water tube boilers, is lower with alleged improved settings than without them.

Scarcely less interesting are the results obtained regarding the prevention of smoke. The data from common furnaces represent them just as they were being operated in regular service. Those from the improved settings represent good, bad and indifferent devices. They show that the maximum smoke with improved devices is but little over half that from the common furnace; while the minimum is reduced to an imperceptible figure. As an average these figures indicate that improved furnaces have reduced the smoke fully 80 per cent. If we were to eliminate from this list all the notably poor devices, the average of the rest would show a reduction of from 90 to 95 per cent. Of forty

trials of improved, or so-called "smokeless" furnaces, during which careful records were kept of the smoke,

3	average	less than half of			1	per cent.
6	"	between	$\frac{1}{2}$	and	1	"
11	"	"	1	"	5	"
7	"	"	5	"	10	"
7	"	"	10	"	20	"
6	"	above			20	"

Hence it appears that smoke averaging less than 1 per cent. is not only possible, but is being secured regularly in every-day service in quite a number of large steam plants in this vicinity.

On page 165 will be found details of an interesting series of trials made by the writer some time ago at the Green Tree Brewery in this city. The boiler plant consisted of four ordinary horizontal return tubular boilers, each 72 inches diameter, 20 feet long, and having 68—4-inch tubes. The boilers are set in two batteries of two each, each pair of boilers having a single furnace. The setting is the Hawley down draft, which is so common in this city as to need no description at this time. The writer discussed down-draft furnaces in general at the Detroit Meeting of the American Society of Mechanical Engineers in 1895. See Transactions of that society, Vol. xvi, page 773.

In the writer's opinion, this Green Tree Brewery plant represents excellent practice, and is admirably designed to secure, in one plant, the maxima of efficiency, capacity and smokelessness. On the first day we ran the boilers at their rating, with damper partly closed; the second day the run was made with damper wide open, but without slicing or disturbing the fires; the third run was made with damper wide open and the fires sliced and agitated, with a view of getting the maximum capacity out of the plant. The results are very interesting. It will be seen that the capacity increased from rating to 81 per cent. and 120 per cent. above rating, while the efficiency dropped from 76.38 to 70.33 and 68.83, the smoke in all three instances being less than 1 per cent. As a whole, this performance has never been equaled, so far as I know, with ordinary tubular boilers, and is rarely exceeded even by the best types of water tube. It demonstrates conclusively that smoke abatement is not inconsistent with the highest fuel economy and the maximum demands for capacity.

On page 167 will be found a summary of fuel analyses and calorific determinations made in connection with some of the writer's boiler trials. They indicate clearly the class of fuel which is commonly met with in this part of the country, and fairly represent the range covered. The high percentages of volatile matter and of ash and sulphur are particularly noticeable. In spite of these drawbacks in the fuel, recent trials of boiler efficiency show that with properly designed boilers

and furnaces, intelligently handled, it is possible to reach practically as high results relatively with these coals as with the higher grades common throughout the Eastern States.

In designing a boiler plant to give the best results under all conditions of service, with low-grade fuels, the following desirable features should be kept in mind:

A. Ample draft; 1 inch of water or even more. Good results cannot be secured with drafts less than ½ inch. Good draft and thick beds of fuel permit the high fire-box temperatures which we have found absolutely necessary.

B. Large ratio of heating to grate surface, so that while burning coal at a high rate per square foot of grate per hour, there is sufficient heating surface to reduce the temperature of the flue gases to 450° F. or less.

C. The combustion chamber should, if possible, be separate from the heating surfaces, so as to avoid their cooling effect. It should be quite deep—30 inches or more.

To secure the very highest results, the gases, after leaving the boiler-heating surfaces at not exceeding 500°, should be passed through feed-water economizers and thence through air heaters. The feed water, leaving the ordinary exhaust heater at a littleabove 200° F., may be raised to over 300° in the economizer, and the heated gases reduced to 250° or less. This reduction in temperature, of course, destroys the usefulness of these gases as draft producers, unless the chimney is very tall. The draft, however, can be better produced by exhaust fans, which draw the air through and out of the furnace and economizer, and discharge the gases at such a height above the roof that they will not be objectionable, thus doing away entirely with the necessity for high chimneys. Still better economy may be secured by placing air heaters in the smoke flue, beyond the fan, or between it and the economizer. Through these the air, entering the ash pit for purposes of combustion, may be drawn, so that the heated gases are finally discharged at a temperature but little above that of the atmosphere. The speed of the fan may be controlled by an automatic regulator, which increases the speed of the fan engine as the steam pressure drops, and reduces it as the pressure increases, thus performing all the functions of an automatic damper regulator. This plan is not experimental or untried, but has already been adopted in numerous large plants.

From the above it is evident that while the best modern water tubular plant, with improved setting, shows an efficiency 60 per cent. greater than the average efficiency of the common tubular boiler and setting, found in this vicinity almost exclusively until a few years ago, there is still room for considerable saving. Whether all these refine-

ments will pay in any given case, can be determined only by consideration of all the conditions. With fuel as cheap as it is in St. Louis, there is, of course, a limit to the amount of money we should spend in improving a plant with a view of economizing fuel bills. As a general rule, however, it may be safely stated that in this year of our Lord 1896, the building of tall chimneys to secure draft, simply advertises the owner's lack of familiarity with modern improvements, or his want of confidence in results easily demonstrated. To this rule there are, of course, exceptions, as for instance, where the plant is small, fuel comparatively inexpensive and money not available, or where other considerations require that the gases be discharged at considerable elevation.

RESULTS OF EVAPORATIVE TRIALS MADE BY WILLIAM H. BRYAN, CONSULTING ENGINEER, ST. LOUIS, MO., ON ONE BATTERY OF HORIZONTAL TUBULAR BOILERS WITH HAWLEY FURNACE, AT GREEN TREE BREWERY, FOR JOHN O'BRIEN BOILER WORKS CO., TO DETERMINE EFFICIENCY, CAPACITY AND SMOKELESSNESS.

Number of Trial	1	2	3
Date . . . 1895	Nov. 19.	Nov. 20.	Nov. 25.
Duration, . . . hours	10	8	8
Number of Boilers in Operation...	2 in Battery.	2 in Battery.	2 in Battery.
State of the Weather	Cloudy, High Winds.	Cloudy (Raining).	Cloudy (Raining).
DIMENSIONS AND PROPORTIONS.			
Kind of Boiler	Horizontal Tubular.	Horizontal Tubular.	Horizontal Tubular.
Dimensions of Shell, Diameter and Length	72 ins. x 20 ft.	72 ins. x 20 ft.	72 ins. x 20 ft.
Number and Diameter of Tubes...	68—4 ins.	68—4 ins.	68—4 ins.
Grate Surface 13 ft. 10 ins. wide, 4½ ft. long . . . Area, sq. ft.	62 24	62.24	62.24
Water Heating Surface . . . sq. ft.	3,385.35	3,385.35	3,385.35
Superheating Surface . . . sq. ft.	None.	None.	None.
Percentage of Air Space in Grate per cent.	47.3	47.3	47 3
Ratio of Grate Surface to Water Heating surface . . . one to	54.39	54.39	54.39
Mean Opening of Damper (percentage of full opening) . . .	37 2	97.0	98
Chimney Dimensions, Height and Diameter	173 ft. x 54 ins.	173 ft. x 54 ins.	173 ft. x 54 ins.
AVERAGE PRESSURES.			
Atmosphere, as per Barometer inches	29.44	29.39	29.225
Steam in Boiler, by Gauge . . lbs. .	95.86	96.17	95.57
" " Absolute . . lbs. .	110.56	110.87	110 27
Draught Suction, inches of water . .	0.6417	1 107	1.05
AVERAGE TEMPERATURES.			
Of External Air . . . deg. F.	36.60	24.2	34.0
Of Boiler Room . . . deg. F.	57 37	54.8	58.44
Of Escaping Gases entering Chimney . . . deg. F.	438.9	584.7	564.9
Of Feed Water entering Boiler deg. F.	71.16	53.123	50.2
Of Steam in Boiler . . . deg. F.	334.8	337.2	334.7
FUEL.			
Kind of Coal	Mount Olive.	Mount Olive.	Mount Olive.
Size of Coal	Lump.	Lump.	Lump.
Calorific Power by Calorimeter British Thermal Units . per lb.	10,965	11,024	10,980
Theoretical Evavaporative Power from and at 212° F., in lbs. Water per lb. coal	11.35	11.412	11.367
Total Quantity Consumed . . lbs.	11,250	17,604	21,750
Total Ash, Clinkers and Unburned Coal . . . lbs.	730	1554.5	2359 5

Proportion of Ash, etc., to Coal per cent.	6.489	8.83	10.848
Total Combustible Burned. . . lbs.	10,520	16,049.5	19,390.5
Mean Thickness of Fire . inches	7½	9	10
COMBUSTION PER HOUR.			
Coal actually consumed . . . . lbs.	1,125	2200.5	2718.75
Combustible act'ly consumed, lbs.	1,052	2006.2	2423.81
Per square foot Grate Surface, Coal . . . . lbs.	18.075	35.35	43.68
Per square foot Grate Surface, Combustible . . . . .lbs.	16.902	32.23	38 94
Per square foot Heating Surface, Coal. . . . . lbs.	0.332	0.650	0.803
Per square foot Heating Surface Combustible . . . . lbs.	0.318	0.595	0.716
CALORIMETRIC TESTS.			
Quality of the Steam (dry steam = 100)	98.6796	99.353	99.201
Amount of Water entrained in the Steam . . . . per cent.	1 3204	0.647	0.799
Amount of Superheating. . deg. F.	None.	None.	None.
WATER.			
Amount apparently evaporated lbs.	83,369.34	118,159	142,910
Amount actually evaporated (corrected for entrainment) . .lbs.	82,268	117,295.16	141,782
Factor of Evaporation	1.1856	1.2045	1.2072
Equivalent Evaporation into dry steam from and at 212° F...lbs.	97,536.118	141,282.02	171,163.77
ECONOMIC EVAPORATION.			
Per Pound of Coal:			
Water actually evaporated (corrected for entrainment) . . lbs.	7.313	6.663	6.519
Equivalent from and at 212° F., lbs.	8.669	8.026	7.824
Per pound of Combustible. Water actually evaporated (corrected for entrainment) . . . . . lbs.	7.820	7.308	7.312
Equivalent from and at 212° F., lbs.	9.2715	8.80	8.827
EVAPORATION PER HOUR.			
Water actually evaporated (corrected for entrainment). . lbs.	8,226.8	14,661.89	17,722.8
Equivalent from and at 212° F., lbs.	9,753.6	17,660.25	21.395.47
Per square foot Heating Surface. Water actually evaporated (corrected for entrainment) . lbs,	2.43	1.33	5.235
Equivalent from and at 212° F., lbs.	2.88	5.217	6.320
Per square foot Grate Surface. Water actually evaporated (corrected) . . . . lbs.	132.18	235.57	284.75
Equivalent from and at 212° F., lbs.	156.71	283.74	343.76
EFFICIENCY.			
Percentage of Total Calorific Power utilized, or Efficiency per cent.	76.38	70.33	68.83
Coal Consumed per Horse-power per hour . . . . lbs.	3 98	4.30	4.384
HORSE-POWER.			
Actually developed on basis of 34½ lbs. water evaporated per hour from and at2 12° F.,horsepower	282.71	511.89	620.16
Commercial Rating, at 12 sq. ft. heating surface. . horse-power	282.11	282.11	282.11
Proportion capacity developed is of Commercial Rating . per cent.	100.2	181.09	219.83
Heating Surface required to develop one Horse-power . sq. ft.	11.97	6.613	5.46
SMOKE RECORD.			
Mean Smoke Production on a scale of 100	.700	0.344	0.98

COAL ANALYSIS (AVERAGE).

Moisture	9.27
Volatile Matter	30.87
Fixed carbon	42.66
Sulphur	5.32
Ash	11.88
	100.00

SUMMARY OF ANALYSES AND CALORIFIC DETERMINATIONS OF WESTERN FUELS.

Principally Southern Illinois Bituminous.

Kind of Coal.	Size.	B. T. U. per pound.	Theo. Evap. Cap'y	Proximate Analyses. Moisture.	Volatile Matter.	Fixed Carbon.	Sulphur.	Ash.
Big Muddy	Lump	12,190	12.62	7.18	28.83	55.58	1.39	7.02
"	"	12,126	12.53					
Murphysboro	"	11,766	12.18					
"	"	11,511	11.92					
Hurricane	"	11,455	11.86	6.84	27.57	53.07	1.72	10.80
Mount Olive	"	11,481	11.88					
"	"	11,352	11.75					
"	"	11,281	11.68					
"	"	11,278	11.67	10.84	31.63	42.37	5.08	10.08
"	"	11,100	11.49	12.04	32.95	41.63	3.28	10.10
"	"	11,085	11 47	11.36	33.15	41.08	4.18	10.23
"	"	11,024	11.41					
"	"	10,980	11.37					
"	"	10,965	11.35	9.27	30.87	42.66	5 32	11.88
"	Run of Mine	10,930	11.31					
"	"	11,233	11.63	11.26	30.39	45.91	3.88	8.56
"	"	11,130	11.52	11.98	28.01	45.83	4.28	9.90
"	"	10,836	11.22					
"	"	10,771	11.15	8.58	29.37	41.55	5.32	15.18
"	"	10,669	11.05	11.70	28.35	40.85	5.58	13.52
"	Nut	11,217	11.61	10.35	30.45	47.29	3.62	8.29
"	"	10,512	10.88					
"	Slack and Nut	10,578	10.95	12.29	30.26	38.50	4.66	14.29
Glen Carbon	Lump	11,481	11.88	10.66	32.74	41.99	4.26	10.35
"	"	11,350	11.75	9.66	31.96	41.82	4.16	12.40
"	"	11,000	11.39	10.78	33.32	41.55	4.25	10.10
"	"	10,836	11.22	10.48	31.64	39.08	4.32	14.48
"	"	10,707	11.09					
"	"	10,512	10.88					
"	"	10,320	10.68	10.52	31.80	39.77	4.21	13.70
"	Run of Mine	11,674	12.09	9.78	32.73	44.75	3.47	9.27
"	"	11,666	12.08					
"	"	11,610	12.02					
"	"	11,041	11.43	10.25	31.14	43.03	3.84	11.74
"	"	10,686	11.07					
"	"	10,707	11.09	10.52	30.96	41.22	4.20	13.10
Collinsville	Lump	11,153	11.55					
"	"	11,000	11.39	9.46	31.09	40.35	5.82	13.28
"	"	10,707	11.08	7.95	31.27	39.20	5.50	16.08
"	Nut	10,232	10.59	9.88	30.50	39.20	2.40	18.02
"	"	9,721	10.06	9.78	26.62	44.61	1.85	17.14
Bryden Royal	Lump	10,232	10.59	6.73	32.71	48.56	1.73	10.30
"	Run of Mine	10,679	11.05	7.46	32.55	43.55	4.66	11.78
"	"	9,848	10.19	7.06	30.90	48.20	. .	13.84
Heintz Bluff	Lump	11,126	11.52	9.26	29.29	43.68	4 42	13.35
"	"	11,029	11.42	6.62	31.36	40.60	6.12	15.30
"	"	10,815	11.20	9.70	32.88	39.86	4.96	12.60
Superior	Nut	9,848	10.19	6.54	29.74	44.02	3.90	15.80
"	"	9,440	9.77	9.92	29.54	41.76	2.50	16.28
"	"	9,336	9.66	9.80	28.12	42.92	2.66	16.50

Kind of Coal.	Size.	B. T. U. per pound.	Theo. Evap. Cap'y	Proximate Analyses. Moisture.	Volatile Matter.	Fixed Carbon.	Sulphur.	Ash.
Gillespie	Lump	9,976	10.33	8.84	29.86	48.45	1.58	11.27
"	"	9,722	10.07	8.60	29.50	50.30	1.36	10.23
Southern Ill.	"	10.905	11.29	7.41	30.81	43.78	4.13	13.87
"	"	10,900	11.28					
Belleville	"	11,230	11.62	10.35	29.27	45.65	3.18	11.55
"	"	11,047	11.44					
"	"	11,021	11.41					
"	Mixed Lump and Slack	10,320	10.69	8.42	30.24	41.16	3.54	16.64
Rentschler	Run of Mine	10,961	11.35	9.87	28.15	45.53	3.98	12.47
St. Clair	Nut	10,578	10.95	10.09	28.15	41.96	4.40	15.40
Wilderman	"	10,300	10.66	10.65	26.30	40.66	4.76	17.63
	Miscellaneous.							
Cherokee, I. T.	Lump and Slack	12,662	13.11	2.—	31.40	50.40	4.50	11.70
"	"	11,997	12.40	2.12	32.10	49.38	4.20	12.20
"	Slack	11,675	12.07	3.62	29.51	48.09	4.00	14.78
"	"	11,353	11.74	4.36	28.35	47.53	4.68	15.08
"	"	10,671	11.03	4.07	27.67	42.12	5.94	20.20
"	"	10,662	11.02	3.81	27.51	42.42	5.30	20.96
"	"	10,513	10.87	4.28	26.57	42.17	5.62	21.36
Hocking Valley	Run of Mine	11,757	12.17	7.72	28.63	55.72	.60	7.33
Pocahontas	Lump	13,029	13.49	1.20	17.28	75.02	.90	5.60
Kansas & Iowa	Mixed Slack	10,900	11.27	4.83	26.28	45.49	5.48	17.92
	Cokes.							
Connellsville		12,850	13.30	.34	.36	87.80	.72	10.78
"		12,850	13.30	.38	.27	88.32	.80	10.23
Gas House		12,300	12.73	.60	.98	82.74	1.08	14.60

GAS PRODUCERS, AND THE MECHANICAL HANDLING OF FUEL FOR SAME.

By C. L. Saunders, Member of the Civil Engineers' Club of Cleveland.

[Read before the Club, October 27, 1896.*]

Producer gas is rapidly gaining recognition among engineers as one of the foremost means of effecting a saving in the cost and an improvement in the quality of manufactured articles, and is being introduced into many of our large industrial establishments.

During the past year several articles describing new gas producers, and discussing the modifications and improvements of the types now in general use, have appeared in the leading engineering magazines. For these new gas producers the inventors claim several points of superiority and economy, such as an increased yield of a new and more permanent gas containing a greater number of heat units per pound of coal, and capable of being brought to the point of combustion with small loss, as also freedom of the products of combustion from qualities deleterious to the material to be heated in the furnace. The various points of superiority of these producers have been so clearly demonstrated, that the engineer contemplating the installation of a gas producer has only to refer to the various articles pertaining to this subject, or to enter into correspondence with the manufacturers of the different gas producers, in order to have at his command all the data required to enable him to choose—relative to fuel, space, location, and the material manufactured —the best adapted to his purpose. Producer gas is unquestionably the cheapest artificial fuel gas per unit of heat.

The following processes have recently come into extended use:

(1) Gas processes, which are essentially water-gas processes. In these the air and steam are admitted at the top and drawn down through an incandescent bed of fuel by an exhauster.

(2) Fuel-gas processes, which are combined water- and oil-gas methods, effecting the decomposition of hydrocarbons injected in small quantities at a number of points.

(3) Gas Producers, with water-trough for bottoms to permit of the continuous removal of ashes, either by manual labor or by a screw conveyor.

(4) Gas Producers having revolving bottoms to facilitate the removal of the ash and clinkers, which are discharged continuously over the edge of the revolving bottom into a sealed ash pit beneath, without interfering with the making of gas.

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Having decided on the type of producer or the system of gas manufacture, the questions to be considered are: The manner of conducting the gas to the point of consumption; and the methods and facilities for cleaning, involving the character and construction of flues, cleaning doors, man-holes, burn-outs and valves. *All* of these questions are important, and, in the final adoption of the small details, the selection of those best suited to permanency and local conditions means economy and increased efficiency in all future operations. Very often a Superintendent finds that his men have failed him and that he must depend on green and ignorant hands. The liability of this to occur at most inopportune times is a factor never to be lost sight of in designing and erecting this class of machinery. The result of ignorance may be the loss of hundreds of pounds of fuel by burning or waste; while carelessness may be the cause of injury to life and limb and the destruction of property.

A thorough knowledge of the kind and character of coal to be used is a primary necessity. It is not necessary to know what the coal could do under many varying conditions determined by exhaustive laboratory experiments, but it *is* of practical value to know what might be expected from day to day, under the ordinary conditions of coal-handling by cheap and ignorant men unaccustomed to working with gas producers.

Briefly stated, the coal used in any system of gas manufacturing should be a coking bituminous coal of good quality, rich in hydrogen, *i.e.*, in volatile hydrocarbons, and should have a low percentage of ash, which should not clinker nor run together under the influence of the heat. The coal should be used fresh, or carefully stored under cover to prevent atmospheric distillation of the volatile matter. It should be as dry as possible at the time of its manufacture into gas, for two reasons: First, to prevent the loss of the heat, which otherwise would be required to evaporate the moisture; and, second, to prevent the condensation or chemical combination of this moisture in the flues, which would precipitate heavy hydrocarbons (tarry matter). These hydrocarbons contain great heating power, and they would thus be lost at the point of combustion.

The coal should be as nearly as possible uniform in size, as this will make level fires which burn evenly. Dust should not be used, as it would adhere to the sides of the bells and hoppers, and form tar, and would interfere with their operation, or it would be carried by the drafts into the flues and deposited there before complete distillation of gas within the particle had taken place, necessitating, besides the loss, frequent burning or cleaning of flues. Neither should large lumps be allowed, as they would require longer burning than surrounding

material and would make irregular fires, some parts of which would be at a white heat while large masses of coal would be hardly heated through. Air and steam soon force their way through these weak spots and escape into the gas space above, burning both coal and gas.

When large coal is used the man attending the producer need poke the fire but little to liberate the gas. On the contrary, if clean fine coal is used, a greater amount of care and attention will be required, in order to prevent the coal from coking together and arching over. To liberate the gas, the bed of coals must be constantly poked, and the ashes removed uniformly, to allow the even descent of the bed of fuel.

The character of the hydrocarbons depends principally upon the temperature at which they are produced. Operating at low temperature gives easily condensed tarry matter (liquid and solid hydrocarbons) of considerable heating power; while with producers operated at high temperature, having the body of the fuel maintained at a bright red heat, the yield of permanent gases and hydrogen is very large, and that of tarry matter correspondingly small.

By the use of a fine clean coal, a large volume of gas will be suddenly generated, giving at the same time a larger quantity of finer and more even ash, which can be handled easily and cheaply. For the production of a given number of heat units a larger quantity of coal will be required, because fine coal is slacked more rapidly by the air, and always contains a greater percentage of ash, than lump of the same quality. With the use of coal having no extremely large lumps, the repairs and delays, incidental to breakdowns, as well as the operating expenses of the coal-handling machinery, are greatly lessened, while the reliability and capacity of the furnace is greatly increased.

The introduction of producer gas into many of our large industrial establishments, and the many new processes of manufacture dependent upon the successful application of gas, have stimulated engineers to devise methods and means to improve all the mechanical construction in connection with the gas manufacture, so as to insure permanency, to reduce the labor of operation and to make the charging and cleaning as nearly automatic as possible, thus reducing the cost of operation and maintenance to the lowest possible point.

There is no way in which this can be more readily accomplished than through a successful plant for handling coal and ash. The most economical and successful plant will be that which best utilizes the force of gravity in its operation. If the conditions would permit the unloading of the coal directly from the cars into the storage bins, from which it could then be carried to the gas producers by the force of gravity, it would be possible to erect an ideal coal-handling plant.

The choice between the several systems of coal-handling machinery

rests with the engineer—each system having its superior and its objectionable points. Preference should be given to that system which has the fewest excessively strong and durable moving parts. Avoid the too common error of building only for immediate needs, and erect the work, even if at a greater first cost, with a view to the *unusual* demands which may be put upon its capacity and strength.

Before deciding on the method of coal handling, it is essential to ascertain the best manner of moving the cars, and to make provision for the storage of both empty and loaded coal cars. Care should be taken to run the grades of the tracks so that when the loaded cars are left by the yard engine, all future moving may be accomplished by simply dropping the cars down a grade, and, when they are empty, leaving them on a side track for removal.

Coal-handling plants may be divided into the following classes:

(1) Plants, beneath whose tracks are coal hoppers, to which the cars are either shoved by an engine or pulled by a cable, and then automatically dumped or unloaded.

(2) Plants having unloading devices by which the coal is lifted out of the cars and carried away.

In the first class we find the following subdivisions:

(1) A single hopper, into which the coal can be unloaded at one point only, provided with a discharge gate emptying into a stationary elevator, which lifts the coal to a conveyor, located over and discharging into storage hoppers above the producers.

(2) Plant as described, except that the overhead conveyor is replaced by a small dump car running on tracks above the storage bins.

(3) A series of hoppers long enough to permit several cars to be dumped or unloaded at the same time, provided with gates opening into a conveyor which carries the coal to a stationary elevator; the remainder of the construction as described.

(4) A series of hoppers or bins long enough to permit several cars to be unloaded at the same time, and provided with a series of gates opening into a traveling elevator, which moves along in front of the bin and elevates the coal into a parallel series of overhead hoppers above the gas producers.

Unloading devices may be divided as follows:

(1) Traveling jib-cranes or cantilever hoists, moving on tracks laid alongside of or elevated above the car tracks. The hoist lifts and operates a patented clam shell or automatic filling and unloading bucket, or a bucket of the ordinary self-dumping character.

(2) Traveling-power shovels which move on tracks laid by the side of, or elevated above, the car tracks and having a drop-bottom bucket-shovel on the end of a movable arm. The bucket is filled by being

forced by the arm down into a coal car. It is then lifted and swung over to one side, and the coal is dumped on the floor, into a hopper, or transferred to a system of conveyors and elevators which carry the coal to its destination.

(3) Unloading-elevators, having a continuous bucket-elevator which is raised and lowered directly over the car and provided with suitable guides in a stationary or movable frame-work, supported by legs on each side of the track. The elevator is lifted, by hoisting-chains attached above, high enough to permit the car being placed beneath. The elevator, while running, is then lowered to the coal car. The front and bottom of the elevator boot being open, the buckets fill with coal as the elevator is lowered, until the buckets just clear the bottom of the car. Then the car is moved along, continuously feeding the running elevator, until the car is unloaded, when the elevator is lifted out of the car.

Any of the classes named, with their several modifications, may be operated by steam or by electricity, and may be combined according to the requirements of the plant, or to the individual preference of the engineer.

Time will not permit me to give a description of the buckets, chains and conveyors which the engineer will have at his disposal for the erection of a coal-handling plant, but he can safely refer to the catalogues of the Hoisting, Conveying, and Link Belt Engineering Companies, and obtain information as to the special work at hand.

Bradley & Poates, Engr's, N.Y.

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REFRIGERATION.

As Applied to Dwellings, Hotels, Hospitals, Business Houses and Public Institutions.

BY ALFRED SIEBERT, MEMBER, ENGINEERS' CLUB OF ST. LOUIS.

[Read October 7, 1896.*]

UNTIL recently ice has been used in the above establishments exclusively to obtain the necessary refrigeration for preserving food, for making ice water, and for preserving perishable goods.

The ice was mostly applied direct, and, therefore, temperatures lower than 38° to 40° could not be obtained, and furthermore the rooms and food thus refrigerated was always moist, there being no way to abstract the moisture necessarily produced by the condensation of the water vapor in the air.

Later, the ice was mixed with common salt in large tanks, a strong brine resulting, of a temperature of about 10° F. This brine was then circulated by a pump through coils located in the rooms to be refrigerated.

In this manner temperatures of 15° F. and a dry atmosphere in the boxes could be obtained, but the process was expensive, as the salt once used had to be wasted.

The refrigerating machines used at present furnish low temperatures and dry atmosphere at little expense where power can readily be had.

Electricity is, as yet, too expensive, since the cost in small quantities is 6 cents per horse-power hour. Gas engines, with gas at 80

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cents per thousand feet, furnish the indicated horse-power at about 2 cents, while the actual horse-power costs 2½ cents. Gasoline engines furnish power for about 1½ cents per horse-power, but are undesirable on account of danger of fire, and insurance companies therefore object to them.

Where a steam plant is already on hand, with or without an engine, it is easy to produce a horse-power for 1 cent per hour, if the wages of the attendants who are needed for other purposes are not considered, and in such cases it pays to put in a refrigerating machine.

Where, however, no steam plant is available, the only salvation at present is a coal-oil engine, using oil of 150°—220° flash point and furnishing the brake horse-power for 1 cent per hour.

Against such an engine no insurance company will object, and, since it is entirely automatic, it will need no attention for, say, ten hours after once being started.

Even when the load is taken off, the speed changes only at the very moment, so that if the load is taken off after one half minute, an engine whose standard speed is 230 revolutions per minute, will still register only 233.

In very small refrigerating machines we have to allow two or three brake horse-power per ton of ice capacity, and in large machines, according to the temperature of the cooling water, 1¼ to 1½ horse-power per ton of capacity. In ice machines, one ton capacity is the capacity of melting one ton of ice in 24 hours.

When a machine, therefore, is to replace the ice formerly used, it is easy to calculate the expense of power, but it is not so easy to calculate the capacity of a refrigerating machine when certain work is to be done which has not been previously done by ice, and a refrigerating expert should then be consulted.

No general rules can be given because the nature of the insulation, the location, and the size of the rooms to be refrigerated have to be considered, also the number of times doors are opened, and the nature of the material put in the boxes greatly affect the problem.

The next question to consider is that of water.

We need, per ton of refrigeration, two gallons of water, if hydrant water is used, which is about 85° in high summer, and one gallon per ton of refrigeration, if well water from 56° to 60° is used. Now city water, in small quantities, costs about 15 cents per thousand gallons, and, since a one ton machine would use per day 24 x 60 x 2=2880 gallons, the water would cost 43 cents.

But frequently this water can be allowed to run into a tank and can be used for other purposes, such as making steam, washing purposes, flushing closets, etc.

The water can be used for any purpose whatever. It is just as clean as it was before being used by the ice machine, only from 15° to 30° warmer; 30° in the case of well water and 15° in the case of river water.

Having ascertained the first cost of the apparatus, we can now calculate the actual cost of operating it, counting running expenses, interest on capital and deterioration, and can ascertain whether it will be cheaper to refrigerate with ice or with the machine, provided satisfactory service can be obtained with ice.

Frequently, however, the inconvenience of handling the ice, the expense required for storing it, the wet atmosphere and the unsatisfactory temperatures obtainable, outweigh even an excess of expenses.

The refrigerating machines are used for the cooling of rooms, the making of ice, the freezing of water in carafes, the making of ice-cream, and the cooling of air to be injected into living rooms.

We have now to decide which system of refrigeration we shall adopt, the direct or the indirect.

In the first, the direct system, ammonia is circulated through pipes located directly in the rooms to be refrigerated, while, in the second case, the indirect system, the ammonia is circulated in pipes located in a brine tank, cooling the brine, which then in turn cools the rooms, it being circulated through pipes provided in the rooms.

Ice making, carafe freezing, and ice-cream freezing are always done by the indirect system, while the cooling of the air is more economically done by the indirect system, but can be done by the direct system when blown into rooms.

The cooling of rooms direct should be done by the direct system, if possible, or (when it is found necessary to stop the machine over night to save attendance, and when the boxes are small and will be used over night) by a combination system.

To use the indirect system for small boxes when the machine stops over night is no advantage; first, the brine tank must be made considerably larger in order to store sufficient cold brine, which can be circulated through the cooling pipes in the rooms while the machines are stopped.

And, second, in order to circulate the brine, a pump must be kept going, which needs attention and power, so that either a boiler must be kept going or a motor of some kind, which also need attention.

The indirect system for rooms to be refrigerated is really an advantage only when the rooms are very small and the machine runs continually, since it is difficult to regulate the temperature of such boxes by the direct system, the number of running feet of pipe in boxes being so small that the liquid inlet cock cannot be adjusted accurately enough, and either too much liquid or none will enter the pipes.

In the direct system no brine tank, nor brine pump is required, and, while the brine pipes are somewhat cheaper than the ammonia pipes, the price of the brine tank and pumps more than counteracts this difference.

While the life of ammonia pipes is infinite, the life of brine pipes is about three years. The pipes themselves would last longer, but the threaded ends give out, and this necessitates the removal of the pipes just the same.

Further, it is not always easy to provide space for the brine tank and brine pump, and then the eventual leaking of brine tank and the adding of brine are undesirable features.

In other words, there are only very rare occasions where the indirect system should be used.

The combination system, however, is admirably suited to the cooling of small rooms or boxes. It consists of ammonia pipes, which are partly exposed to the air of the box and partly submerged in weak brine.

A galvanized iron trough is suspended from the ceiling and filled with weak brine, and, in the space between ceiling and trough, one, two, or more horizontal rows of pipe are suspended.

In the case of one row, the pipes may be one-half submerged, and in the case of two rows, one row may be submerged and one row exposed to the air.

The trough, must, of course, be so arranged that the air can reach the space above it on one side, pass over the pipes, become cooled and descend on the side opposite to that from which it started.

This is done by making the trough narrower than the boxes, leaving a passage for the air on each side.

If the box is wider than about three feet, it is better to provide two troughs, leaving a double passage between the two troughs and a single passage on each side.

The warm air will then ascend through the central double passage, and divide, one half passing over each trough and descending through one of the single side passages.

Of course, sufficient spaces must be left for the free passage of the air.

The advantages derived by the use of the combination system (Richmond Patent), are the following:

First. Easy regulation of the liquid. When it is the intention to run the machine only 12 hours per day, sufficient pipes must be provided to do the cooling required for 24 hours in 12 hours, and, therefore, twice the amount of pipes must be erected, consequently the range for the liquid to act upon is increased.

But, since a part of the pipes (the part further away from the inlet) is submerged, the contact with the medium to be cooled is better, and considerable more heat can be transmitted by each foot of pipe, hence there is little chance for the liquid to leave the coils as such, and accumulation of refrigeration by the cooling, and much more by the freezing of the weak brine, is obtained. The brine is made weak so that it will freeze at about 28°. It can then easily keep a box at 34° as long as it is melting, and, even melted, the brine itself, as a liquid, can absorb heat until its temperature reaches 34°.

It will be seen that in this manner a storage of refrigeration is obtained, which is very convenient, takes up very little room, and works automatically, storing whenever there is surplus refrigeration.

The making of ice is rather a cumbersome affair, and does not pay in small quantities.

Ice made of raw water has a snowy appearance, and the water must be carefully filtered in order to avoid coloring.

A distilling apparatus takes up much room and is expensive. Besides, the vapor rising from the steam condensers and reboiling tanks must be carried off, and this is seldom convenient in a dwelling house.

For hotels, however, where it is easy to obtain distilled water, there being quite a large quantity of surplus exhaust steam on hand, it pays to make ice.

In dwelling houses, freezing the water in carafes can easily be accomplished, no distilling appliance being necessary, since the appearance of the ice formed in the carafes is not objectionable; and, if a little opaque ice is wanted, small ice cans can be placed in the pockets provided for the carafes and the water therein frozen.

A small place can be reserved for the ice-cream freezer, which need be of no special construction, and the motor which is used to circulate the brine in the carafe tank can be connected to the stirring apparatus of the ice-cream freezer.

The cooling of the air for living rooms, fever rooms, hospitals, libraries, etc., is another useful and important application.

There the condition of the atmosphere in regard to moisture plays an important part.

It is well known that air and water vapor exist together in our atmosphere, the percentage of water vapor varying from 35 to 100. According to Dalton's law, two gases or vapors like the above exist together, just as if the other was not there, the temperature of the mixture determining the pressures and in consequence the weights of the water vapor, provided the percentage of the moisture has been obtained by a hygrometer of some kind.

In one cubic foot of air there exists therefore one cubic foot of

water vapor. Assuming the temperature of the air to be 85° we find the pressure 0.592 pounds and the weight of one part of it 0.00182 pounds. If now the percentage of moisture is 60, we know that this cubic foot of mixture contains $0.00182 \times \frac{60}{100} = 0.00109$ pounds of water vapor.

From the above and by the use of a steam table it will be readily seen that if we cool air, we increase rapidly the percentage of moisture, finally condensing part of it, which is, however, a very objectionable occurrence in a living room or a fever room.

If, therefore, we do not want to abstract the moisture by heating the air after having cooled it below the desired temperature and lost water vapor by condensation, we must be satisfied with a reduction of about 10° F. in the temperature of the air.

For instance, if we take the previous example and fix 75 as a limit for the percentage of moisture permissible, we find that taking 0.00109 as being 75 per cent. of the weight of one cubic foot, that one cubic foot would weigh 0.001336 pounds, which would correspond to a temperature of the cooled air of 75° (see steam tables). If we should cool the air any further the percentage of moisture would exceed 75, and this is not permissible.

Taking, now, the case that we are required to furnish air at 60° F. containing only 50 per cent. moisture, the air to be cooled having a temperature of 95° and a maximum percentage of moisture of 75, the question is, how low must we cool the air in order to condense sufficient water vapor to obtain the proper amount of moisture when the air is heated again to the temperature desired.

We have air at 95° and 75 per cent. moisture, consequently each cubic foot of air contains (see table) $0.00245 \times \frac{75}{100} = 0.00184$ pounds.

We have air at 60° and 50 per cent. moisture. Each cubic foot of air contains then (see tables) $0.00082 \times \frac{50}{100} = 0.00041$ pounds. of moisture, or we have condensed $0.00184 - 0.00041 = 0.00143$ pounds

Since we want to retain only 0.00041 pounds of water vapor, we must cool the air to such a temperature that, when saturated, it contains 0.00041 pounds. Consulting the table, we find that this takes place at 40° F.

To recapitulate, we have first to cool the air of 95° to 40°, and then to heat it again to 60°, in order to obtain the desired conditions.

The work of refrigeration required for this is as follows:

Neglecting the fact, that owing to the pressure of the water vapor (about one-half pound), the pressure of the air itself is not quite atmospheric pressure, the sum of the pressures of the water vapor and the dry air being equal to the pressure of the atmospheric air.

We can divide the work into four parts:

1. To cool the dry air.
2. To cool the water vapor.
3. To condense the water vapor.
4. To freeze the water vapor when the direct system of cooling is used.

1. AIR COOLING.

Weight of cubic foot of dry air at 95° = 0.0728
Specific heat of dry air at 95° = 0.2377
One cubic foot requires 0.0728 × (95° — 40°) × 0.2377 = 0.941

2. WATER VAPOR COOLING.

Specific heat of water vapor about 0.5
One cubic foot requires 0.00041 × (95°—40°) × 0.5 = 0.012 th. u.

3. WATER VAPOR CONDENSATION.

Average latent heat = 1000 th. u.
One cubic foot requires 0.00143 × 1000 = 1.43 th. u.

4. WATER FREEZING.

Latent heat of congealing 1.42 th. u. 0.00143 × 143 = 0.203 th. u.

2.586 th. u.

It will be seen how small is the amount of work required to cool the air direct, and what an important role the water vapor plays. It will be further seen that the indirect cooling system is preferable for air cooling, and that only water should be used as the circulating medium, because then there can never be obtained a temperature of air below 32°, and no freezing of the condensed vapor can take place.

Besides, it is much more economical to have a medium at higher temperature, say, about 34°, because then the refrigerating machine can be worked with about 40 pounds suction pressure, while, if the brine of 20° were used the machine would have to work with about 25 pounds sunction pressure, which would mean that in the first place with an expenditure of about 2 per cent. more fuel, 37 per cent. more refrigeration can be obtained. Twenty-five pounds pressure is the usual suction for machines working on the direct and indirect cooling system, also when freezing water in carafes.

The air cooling is generally combined with the heating of the building, either by steam or water.

The radiators are located in air ducts and air is blown over them. In winter, steam or hot water is circulated through them, and in summer cold water, if necessary. Of course an extra radiator for reheating the air must be placed behind the radiator cooling the air; but, as already explained, this will be necessary only when lower temperatures are wanted.

For ordinary living rooms, it is considered that furnishing air cooled 10° four times every hour will have a very agreeable effect, and will purify the air in the room.

RECENT PRACTICE IN RAILROAD SIGNALLING.

By George W. Blodgett, Member of the Boston Society of Civil Engineers.

[Read before the Society, September 16, 1896.*]

The last paper on railroad signalling read before this Society seems to have been that presented, in 1886, by Mr. G. R. Hardy, who presented the subject in a general way, with special reference to the then recently installed system of interlocking for the junctions and terminals of the four tracks of the Boston & Albany Railroad, from Boston to Riverside, while the writer treated of the automatic signalling of the remainder of that portion of the road.

It is not the intention of the author to review any considerable part of the contents of these papers, but for the benefit of those who have more recently become members of the Society it may be desirable to refer particularly to some of them.

It is the purpose of the writer, however, to confine himself, in the main, to the consideration of the progress that has been made in the last ten or twelve years in railroad signalling and of the standard practice of to-day so far as it is well established. He will first take up interlocking at terminals and junctions, and afterwards refer to block signalling, both manual and automatic.

So far as the writer knows, the Saxby-Farmer interlocking machine was the basis and the general type of all the machines for mechanical interlocking which are in use in this country to-day. For the benefit of those who are not at all familiar with the subject, he will say that this machine consists of a series of pivoted levers standing in a nearly vertical position side by side in a frame, and having a motion forward and back in a vertical plane to the extent of about 45° to 60°. All the switches in the vicinity are connected by rods to some of these levers, all the signals (usually by wires) to certain others, while the remainder of the levers control facing-point locks and detector bars, the object of which is to prevent the movement of a switch while a train is passing over it.

There is also a series of sliding pieces called locking-bars,—one for each lever—and other parts, either sliding or rotating, according to the style of machine. To the locking-bars are attached lugs or tappets, which are so arranged as to engage with the sliding or rotating pieces belonging to other locking bars and prevent their motion, except at particular times. Fig. 1 is a front view of such a machine, Fig. 2 an end view, and Fig. 3 a view of some of the details of the locking gear.

* Manuscript received November, 1896.—*Secretary, Ass'n of Eng. Socs.*

The levers are arranged in certain groups or combinations. These belong to consecutive movements which are required for the preparation of particular routes. Out of all the levers in the machine (of which there may be five, ten or a hundred) only a few, it may be half a dozen, can be moved; while all the rest are locked fast in their normal position. Those that are free control the first step necessary in the preparation of the several routes, which may or may not conflict with each other. All of those which do not conflict may be left open at the same time without danger of collision. Of the others, only alternative routes can be used; the selection of one, and the movement of the first lever of the series belonging to it, locks fast all routes which would be inconsistent with it.

So long as trains obey the signals it is practically impossible, no matter what the signalman may do, for him to so arrange the switches and signals that each of two trains can be given at the same time a signal to pass over the same piece of track.

Which levers shall be used, and which shall be locked, and which unlocked by any proposed arrangement of switches and signals, is determined when the machine is set up by a study of all the train movements to be provided for and of their relation to each other. It follows, therefore, that each machine must be designed for the place where it is to be used; and the work it is to do must be known and provided for beforehand.

Where trains are run by telegraph, all the traffic on a division is under the control of the train despatcher of that division, and so, at a junction or yard protected by interlocking, it is a vital part of the system that all the movements must be under the absolute control of the signalman.

Still further, in any of the well-known systems of block signalling, a clear signal means only that the train *has permission* to proceed; whereas, in an interlocking system, the clearing of the signal indicates that the movement it controls *must* be made, and at once, in order to clear the track for others.

The semaphore is still the form of signal ordinarily used, and, except in a few cases, every train movement has had a signal belonging to it which could not be used for any other.

Formerly, only the two switches of a cross-over were attached to the same lever, each thing to be done requiring a separate lever. The changing of a single switch then necessitated three movements (or *five* if the signal be included), and, as the limit of a signalman's capacity for rapid motion is soon reached, in a machine where there are many levers, a second, third, or even a fourth man soon becomes necessary, each working at a different part of the machine, in order that several train move-

ments may take place at once when they can afely do so. This enormously increases the expense, and decreases the safety of operation to a certain degree; and furthermore the locking becomes more and more complicated.

During the last ten years it has become more common, in large machines, to diminish the number of levers required by attaching, where practicable, other movements in the series; such as connecting to a switch lever the lock and detector-bar which were formerly attached to a separate one. Such a switch lever has three distinct functions in different parts of its stroke; first, the switch is unlocked, say by the first third of the movement; the second part of the motion changes the switch, while the remainder of the stroke locks the switch in the new position.

In some machines a still further function was added to the lever, viz., the clearing of the signal; but, as the practice seems to have been entirely abandoned (in mechanical plants at least), I judge it was found impracticable or unreliable.

A valuable addition to the advantages gained by this grouping of functions, is that the locking is greatly simplified, with a corresponding gain in safety and economy of maintenance.

It was formerly the practice not to require the locking of switches for back-up or switching movements, so that flying switching was possible with such an arrangement of interlocking, and there are still in use many plants in which this can be done; but here is a weak point, and, as the pressure of a constantly growing traffic increases, there is more and more danger that a signalman in a hurry to provide for the next movement, may, by first putting the signal to danger, throw a switch before a train has quite cleared it, and thereby split the train, or that a wheel with a sharp flange may strike the point of the switch and crowd it open. The later and better practice is to lock the switch in all cases where a train is to run against the point.

Another great saving in the number of levers required in a mechanical machine is rendered possible by the use of "selectors," whereby one lever is made to move, one at a time, several signals belonging to converging routes, the particular one to be moved being determined by the arrangement of switches and tracks composing the route to which the signal applies.

This is accomplished by a sliding link or loop in a frame, over which are suspended pivoted bars, each terminating in a hook, so arranged as to engage with the link, if allowed to come into contact with it. The opposite end of each of these bars is connected to some signal in the series, by a chain or wire; all the hooks but one are raised out of contact with the link by cams on rotating pieces con-

nected with the rods operating the switches. One lever moves back and forth in the frame the sliding link, and with it the signal at that moment connected to the link by its hooked rod.

As each route is prepared, the cam attached to the switch rod rotates and allows the hook to engage with the link so that the particular signal desired, *and no other*, will be operated.

A single signal is also made to serve several diverging routes by means of an indicator, consisting of a series of numbers or letters, and placed on the signal post.

Fig. 4 shows such a signal in the all-clear position when route No. 2 is open. The signal would show the same for any other route, except that the figure "2" would be replaced by that corresponding to the route which was then open.

Fig. 5 shows the arrangement of the arms which would have been necessary for the tracks shown in the figure when signalled in the old way. A comparison with Fig. 4 will make at once apparent the superiority of the new method over the old.

When the signal is in the danger position the numbers are all covered by a screen, but when a route is prepared and the signal drawn clear, the number designating that particular route comes into view below the screen. This is accomplished by attaching to the switch lever a device which operates that particular number or letter, but no other.

These two improvements, viz.: the attachment of several pieces of apparatus to the same lever and the use of selectors, have effected, in the later installations of mechanical interlocking, a saving, in the number of levers required, of nearly or quite one third, as compared with the standard practice of a few years ago. In some recent cases coming under the writer's observation, the actual saving was as follows, viz.:—

(1) The re-building of a machine already some years in use reduced the number of levers from 60 to 36, or 40 per cent., although some additional switches and signals were connected to the machine.

(2) A machine where 52 levers are now used would have required, under the old system, 70, or nearly one-third more.

(3) In another case, for the work now done by 17 levers, 32 levers, or 46 per cent. more, would have been needed.

In a fourth case, a machine which now has 24 levers would formerly have had 36, or 50 per cent. more.

These cases, taken at random from a list which might easily be made a long one, serve to show to what extent interlocking machines have been simplified by the adoption of the improvement mentioned and by certain minor details of construction. The saving in first cost is considerable; the decrease in cost of maintenance is on the right side of the ledger; the saving of time is important, but the chief gains are

in the greater simplicity and safety of the locking, which are made possible by these changes of construction.

In interlocking switches and signals in a yard an important advantage is gained by the use of *slip switches* and *movable point frogs*, whereby a single track running diagonally across any number of others, is made to take the place of the large number of cross-overs which would have been necessary under the old plan. [As shown in Fig. 6, where a double slip switch is inserted at every crossing of a straight track by the diagonal ave.]. A cross-over occupies from one hundred and fifty to two hundred and fifty feet in length, but slip switches can be put in a much smaller space. The *exact length* will, of course, depend on the distance between the tracks and on the angle chosen for the diagonal track or "ladder," as it is technically called, which last also depends, in many cases, on the room available.

In many yards all the available space is already utilized, and more cannot be had at any price. In such cases, a growing traffic can be provided for only by the use of every means of saving time and labor. Not the least of the benefits gained is the extreme facility afforded for the transfer of cars or engines from one track to another in making up outgoing trains or in removing empty ones.

The labor involved in the movement of switches and signals in a mechanical machine is so great that in a busy yard, where several operators are required, each works at a different part of the machine, and thus controls a different section of the yard, but in many movements two or more operators necessarily work in conjunction. Generally, several different train movements may be going on at the same time, being under the direction of different operators, the machine itself rendering impossible any unsafe combination of two movements.

The only way yet devised of turning this labor into a pastime and making the work of a signalman so light that a child has all the strength necessary to perform it, is the electro pneumatic system of interlocking lately introduced at a number of important junctions and terminal points.

The principles of a good signalling system are preserved by providing the machine with a system of locking as complete and thorough in all its parts as in a full-sized mechanical machine, but on a diminished scale, say not more than one-fifth or one sixth as large. The first machines set up had no locking. Any of the levers could be moved at any time, and in any order; but, unless moved in the order determined upon in the arrangement of the parts of the machine, no effect would be produced. Hence, an operator had to learn by practice or by arbitrary memorizing which levers he must or could use.

In the electro-pneumatic system the levers of the Saxby-Farmer

machine are replaced by small cranks having a rotary motion through an angle of, say, 60°. These are, in reality, only electric switches. The signals, which are full-sized semaphores of the ordinary pattern, are connected to a piston moving in a cylinder and actuated by air under pressure, which is supplied by a pump to a reservoir, and thence distributed about the premises by pipes to the cylinders of all the switches and signals in the vicinity. The valves which admit air to the cylinders are operated by electric currents, which are themselves controlled and directed by the changes of circuit produced by the manipulation of the cranks at the machine.

If the operator turns a crank, the first part of the motion simply completes a circuit through an electro-magnet at the switch. This opens the valve and allows compressed air to enter the cylinder at one end and push the piston to the opposite end. This changes the switch, and, at the end of the stroke, a very ingenious device locks it in the new position. Until this has been done, the further motion of the crank is prevented by a stop, which is removed by a return current from the switch *after its movement is finished*, and not before. The completion of the movement of the crank may now be made. This sends a current of electricity to the proper signal, changing it from the danger to the clear position.

In front of the signalman is a small-scale model of the tracks and switches in that part of the yard which the machine operates, and on this are repeated all the changes that take place in the tracks in the yard itself; so that the signalman has constantly before him a diagram of the actual position of the switches and tracks. Should a switch fail to operate, or even fail to be properly locked, no return current would be sent and no signal could be given; also, no change would take place in the tracks of the model.

Fig. 7 shows a front view of an electro-pneumatic interlocking machine, and Fig. 8 a rear view with the casing removed.

The latest and best example of this system is at the Union Terminal Station, in this city, and it needs only a visit to "Tower A," on the Charlestown side of the drawbridge, to enable one to see how marvellous is the progress that has been made.

This work is especially interesting, because the larger part of the apparatus is located on one side of the channel, while the machine which operates it is on the other side; yet it works as well as if close at hand. It is difficult to see how any other than electrical means could have been successfully used for the multitude of controlling or operating circuits which lead out from this tower and pass under the channel, but which must not be permitted to obstruct the water-way.

Derailing switches have not come into general use, and, so far as

the writer's observation has gone, they develop, when used in the ordinary manner, at a junction or crossing, a danger nearly as great as that against which they are supposed to guard. In several cases that have come to his knowledge the derailed train has blocked the tracks when it might have gone over in safety except for the derailing switch.

The much discussed and still unsettled question of the proper lighting of semaphores at night has received its due share of attention, but there is at present no more sign of agreement on this subject than formerly. It is still common to use a red light for danger and a white one for safety in spite of the fact that a white signal light can easily be confounded with another light seen in the same general direction, especially in crowded towns; and that more than one case is known where a red glass broken out of a semaphore has shown a white light when the signal was at danger, and where a wreck was the result. Were green adopted as the color for safety signals, such a derangement as the breaking of a glass could never lure a train into danger, because it could never produce the safety signal. The Railway Signalling Club, with headquarters at Chicago, has given much consideration to this subject in the last two years, and, at the end of a long report, it recommends that red be the standard color for danger in all stop signals and white the standard for safety, because its members see no prospect of bringing about uniformity except by abandoning green for safety signals, although they practically admit its superiority over white; they intimate, however, the breaking of a glass is so improbable, that it is not worth while to provide against it.

Electric locking is used to some extent, but has not grown into the general favor that at one time seemed likely to greet it. Some of the first installations were so contrived that when a signal was drawn clear it was locked in that position. So far as the author knows, he was the first to call attention to the dangerous character of this practice, and to maintain that nothing should ever be attached to a signal to lock it in the all-clear position, and that it should always be in the power of a signalman to put the signal instantly to danger and stop a train, should it be necessary in order to avert a collision, even though the train had begun to occupy the route over which the signal gave the right of way.

The signalman, however, should not be able to change any of the switches, or to interfere in any way with the route until the train has passed, and here comes in what the writer conceives to be the legitimate function of electric locking, viz.: to secure to a train a perfectly safe passage when once it has begun to occupy a route, but to leave it still under the control of the signalman until the critical point be

passed. Hence every signal should be so arranged that it can be put instantly to danger, while the switches remain locked fast, should the train have accepted its right of way, until they are passed in safety.

In manual block signalling the author knows of no changes in practice worth mentioning, but the "Syke's Lock and Block System" has made commendable progress. In this system each man's signal lever is provided with an electric lock, which is applied automatically, but which can be released only by the signalman in advance; and the signalman, when he has once unlocked the signal in his rear, in order that it may be set clear, cannot again do so until the train already in the block has gone out. For this he must set his own signal clear, and this requires his lever to be unlocked by the man next in advance. When this signal has been cleared, and restored to danger behind the train, he may again unlock the lever of the man in his rear, but it is practically impossible for him to do so before.

There is required, therefore, the combined action of two men to get a train past a signal, and that of three men to get it through a section. Used in its integrity, there is almost no possibility of a collision.

The general arrangement of this system is shown in Fig. 9, which is a diagrammatic view of three blocks of a double-track railroad equipped with signals. Fig. 10 shows a front view, and Fig. 11 a side view of the machines in common use.

This system was applied to fifty miles of the New York, Lake Erie & Western Railway several years ago, but was abandoned, after a year of trial, because the blocks had been made so long that a train could not run from one signal to another before a following train would be waiting to enter the block. It has been put on the New York, New Haven & Hartford Railroad from New York to New Haven, and on four tracks of the New York Central from Albany to Buffalo, where it works well. It is far safer than a simple block system, but costs more for its maintenance. Indeed, the expense is the chief objection that can be brought against its adoption. Also, the fullest degree of safety would require the complete equipment of the track with rail circuits, thus making it still more costly, but with a corresponding gain in safety.

It is in the use of automatic signals that the chief advance has been made in the last ten or twelve years.

In two important particulars solid ground has been gained, and there is little fear of the reversal of present practice in regard to one of these particulars, or of the failure to ultimately adopt the other. Firstly, it is now well established that a continuous rail-circuit is a vital part of a first class automatic signal system; and, secondly, in an ideal system the signals should stand normally at danger and be cleared by

the train in advance of itself (provided the block is unoccupied, the track continuous and the switches all set for the main line), and set to danger again as soon as the train reaches the block.

Any derangement which puts such a signal out of service leaves it showing danger, and not all clear, as was formerly sometimes the case, thus giving a possibly false indication of security when, in reality, the apparatus is inactive.

The author's continued experience in another direction has served only to confirm the judgment he formed many years since, viz., that it is exceedingly important that the engineman of an approaching train should actually see the signal move from the all-clear position to that of danger as he enters the block, and hence that the point from which the operation of the signal takes place should be somewhat in advance of it.

The author is well aware that this view is not accepted by some railroad managers of the highest authority and of wide reputation in other directions, but without much familiarity with automatic signals, and while he respects their opinions he has seen no good reason to change his own, fortified, as it is, by a long practical experience and corroborated by what he considers a very significant fact,—viz., that while he knows of changes in practice from so placing signals that they should *not* be seen to operate, to locations where the change would be visible, he has not heard of a single case where a change has been made in the contrary direction.

The fact that a signal is to be worked by a train and not by hand renders it wise that it should be under as strict surveillance as possible, and hence its operation for every train that passes should be observed. An engineman can do this with no appreciable addition to his labor (since he must observe the signal at all events), and he is vitally concerned. He is usually a man of greater capacity than most of those on the train with him, and the author believes that where this practice is the rule, the enginemen themselves would be the most unwilling to change it. Should all work well, there is nothing for the engineman to do; but if any signal fails to operate normally, he may, in a single moment, note the fact, and at the next convenient point have the information transmitted to the proper parties. Much valuable time is thus saved, and more efficient service obtained without any perceptible increase of labor or of expense.

In conclusion, the author thinks that it may be confidently asserted that in no single direction can a limited sum of money, available for improvement in the service of a railroad, be more wisely spent than in the erection of automatic signals. One of the best can be erected at an average cost of perhaps $500, and maintained at not

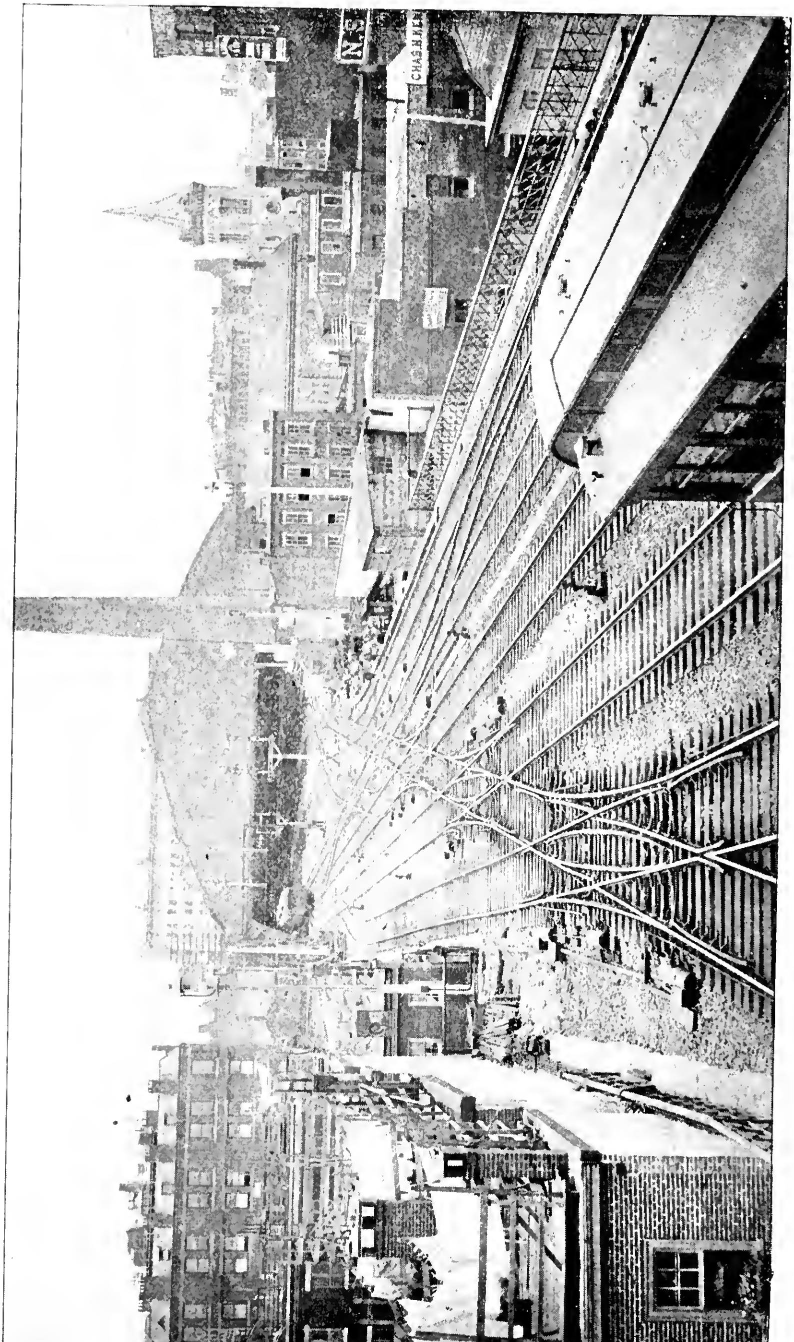


Fig. 6.

exceeding $100 per annum. The average cost in his own experience has been considerably less than this.

A very slight derailment or collision avoided would pay the yearly expense, and a single freight car saved would pay for the installation.

DISCUSSION.

Prof. C. Frank Allen.—There is one point touched upon by the author in regard to which I disagree with him, viz.: the use of the derailing switch. It must be admitted that where there is no derailing switch, a train which runs by a signal may often go on its way without causing an accident, while if there is a derailing switch, the train will go into the ditch, but I do not think this a proof that a derailing switch should not be used. Such a view fails to take sufficiently into account the element of human nature. Many an engineer would sometimes run by a signal if he thought there was little probability that any harm would result from it. It is human nature for a man to do that. But an engineer would, as a rule, be very careful not to run by a signal if he knew that he was sure to run through the derailing switch and into the ditch. When a train goes into the ditch, the railroad officials know about it; whereas, if a train has simply run by a signal, they probably will never hear of it. The very fact, mentioned by the writer, that a train may run by a signal without meeting with an accident, is, if the engineer understands it, an argument in favor of using a derailing switch. It is true, of course, that when running at great speed, a serious accident will probably result if the train does run through a derailing switch, but, the greater the speed, and the more serious the probable result, the less is the liability of the engineer to make a mistake. If the failure to observe the signal is sure to result in a serious accident to the engineer and to others, and if he knows this, it is probable that he will be more likely to run by a signal than to deliberately run into a train squarely in front of him. That railroad discipline can be counted upon to secure the proper observance of signals, is only partially true. A very serious accident recently occurred on the Pennsylvania Railroad, where this discipline must be better than on most other railroads.

Mr. E. K. Turner.—I can hardly agree with Mr. Blodgett in his condemnation of derail switches at crossings. From practical experience with several of these devices, extending over several years, I have found that after the derail switches had been used long enough for the men to become accustomed to them (that is, to learn that they were in the track), very few derailments occurred. The knowledge of the fact that, if a signal at danger is passed, the engine will certainly be de-

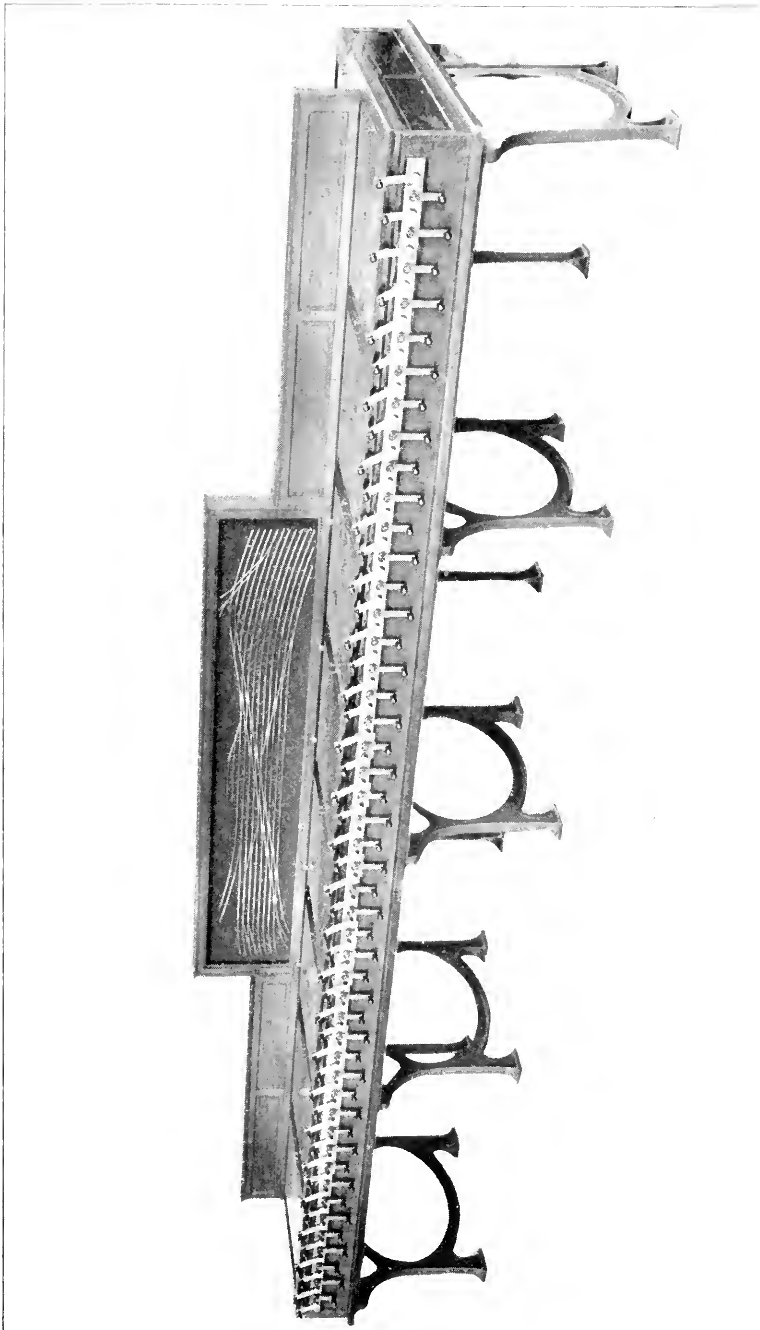


Fig. 7.

railed, makes the engineman more careful in observing the signals. Thus the moral effect is great.

If an engine is derailed it makes its own record and the officials need not ask for or depend upon the report of any employee concerning the violation of rules by another employee.

Of course, with the use of derail switches it is necessary to have strict discipline, every man must have the certainty that a derailment, caused by his failure to observe signals, or to obey orders relating to them, will be followed at once by punishment. If this is relaxed in the slightest degree, the moral effect is lost.

Mr. George F. Sampson.—In discussing this subject of derails it seems to me proper to mention the use of torpedoes connected with an interlocking system, and placed on the rails automatically so that they are exploded by the locomotive and give warning if any train improperly passes a signal set at danger. I am informed that they are used extensively in France, where derailing devices are seldom used and that they are looked upon with considerable favor by some of the best authorities on this subject in our own country. It would seem to me a fruitful field for investigation.

To be sure, an interlocking system is a system of signals designed to prevent accidents, and it is, on that account, best to have the signals observed rigidly according to rule, without being too much complicated with additional devices to tax the mind of the locomotive engineer; but I believe that we should have in mind, as the first object to be obtained—the prevention of all accidents of every kind, including derailments, even if it should prove impossible to detect an offender, a condition of affairs, however, which seems hardly probable.

I am told that, in France, torpedoes are automatically connected with each signal. While I do not see the need of such extensive use, it seems to me that the lever and its fixtures, in an interlocking machine, ordinarily used to throw a derail, could be put to better use in operating a device for placing torpedoes on the rail at such distance from the point of danger as to give warning in addition to that given by the signal arms.

It strikes me that there are but few, if any, men employed as engineers who would fail to bring their wandering senses back to duty with such warning given, while cases are quite numerous where men, having served without accident for a working lifetime, have lost their lives through failure to observe a signal.

Mr. Turner.—Regarding the use of torpedoes in place of derail switches, such use is better than nothing, but does not give that certainty of protection from collisions which the derails give. With the use of torpedoes, it is difficult to locate the violation of rules.

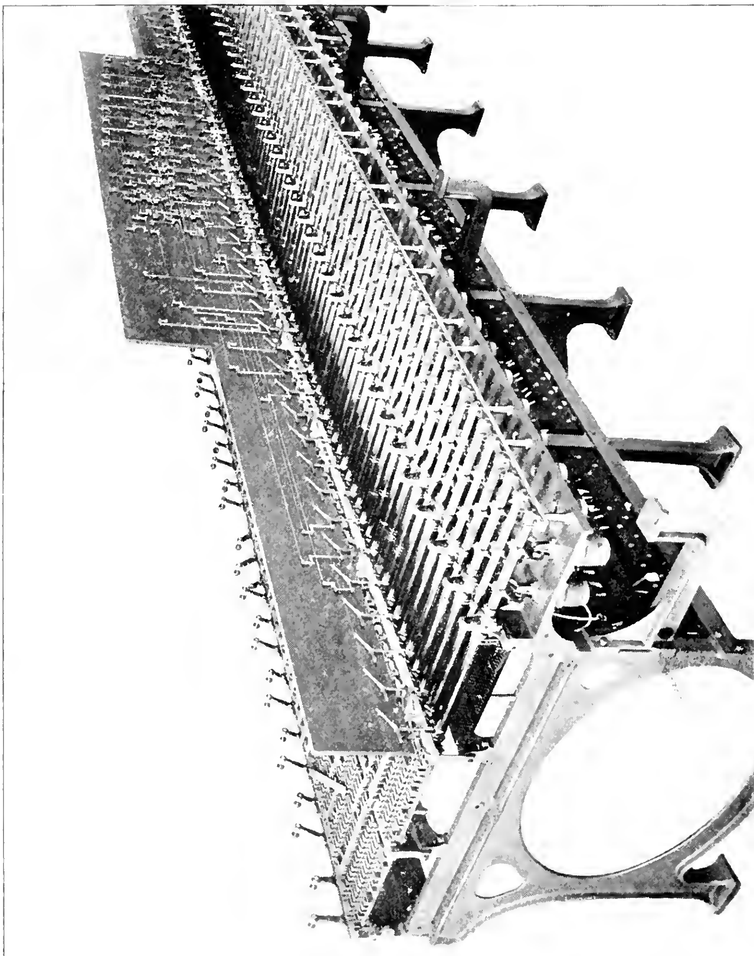


Fig. 8.

In many cases the bad results of derail, noted by Mr. Blodgett could be prevented by the use of sand-covered rails, or of a spare track on to which the engine might be switched instead of on to the ground. But I believe that, in most cases of crossings which are to be passed over by the trains without previously coming to a stop, the safe course is to use the derail switch, and that some of the bad crossing collisions which have occurred would have been prevented by such use.

Unfortunately for the derail switch, the prevention of accident is rarely credited to the device, while the annoyances caused by throwing an engine into the ditch is sure to be charged to it.

FIG. 9.

DIAGRAM of SYKE'S SYSTEM
APPLIED TO DOUBLE TRACK

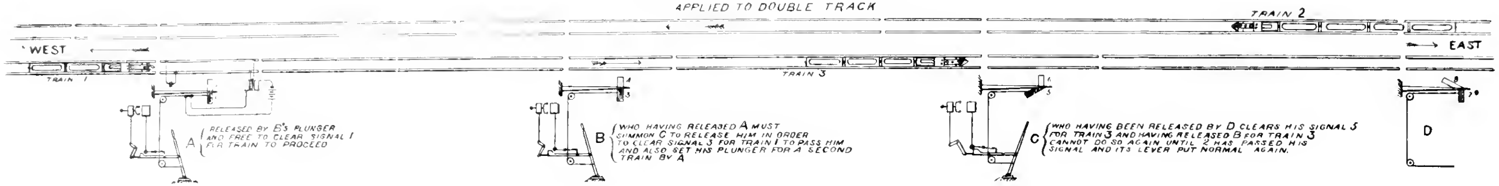


FIG. 4.

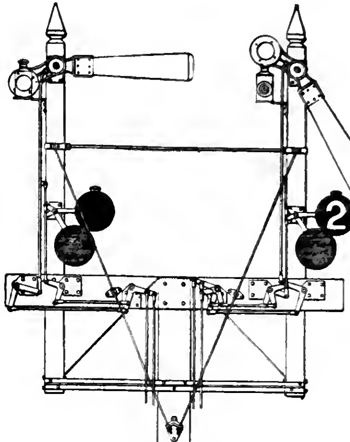


FIG. 1.

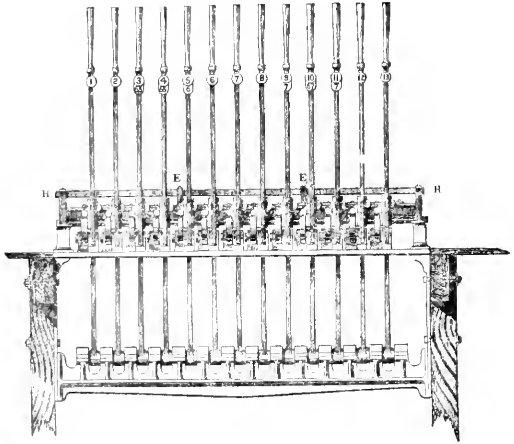


FIG. 2.

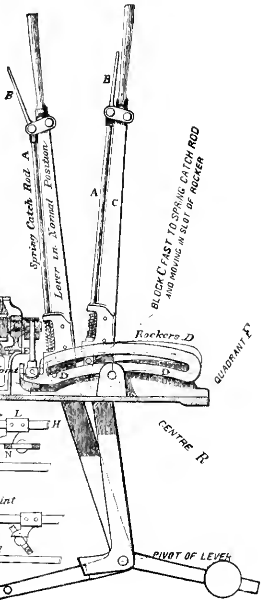


FIG. 3.

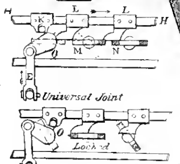


FIG. 10.

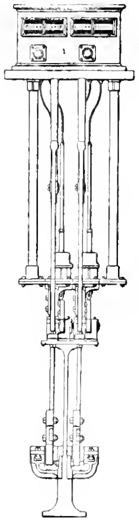
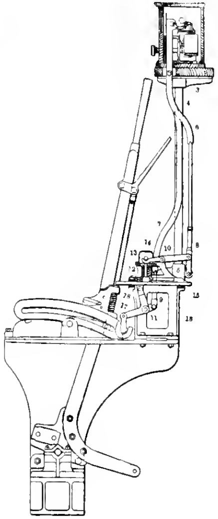


FIG. 11.



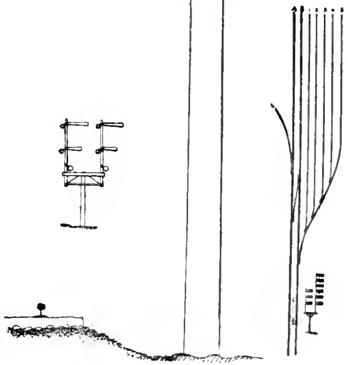


FIG. 5.

THE GALVESTON HARBOR WORKS.

By W. J. SHERMAN, Member, Engineers' Club of St. Louis.

[Read before the Club, September 16, 1896.*]

THE quaint little island city of Galveston, at the northeast end of the long, low and narrow ridge of sand bearing the same name, was once the base of operations of the bold pirate Lafitte. History records no appeals for harbor improvements during that early period; but there seems to have been sufficient water on the bar for the movement of his piratical fleet.

Texas was a State of Mexico, and commerce made few demands upon the rivers and harbors along the barren coast. Later, the people of Texas organized themselves into an independent republic, and commerce began to thrive. To-day they comprise a State of the American Union: this State, an Empire in itself, as great as the combined area of Ohio, Indiana, Illinois, Michigan, Kentucky and Tennessee, and possessed of resources unlimited, which, under the fostering care of the men of the North and East, are being developed with wonderful rapidity.

Before the days of the railroads, and up to the time when rail connections were made with St. Louis, New Orleans and Kansas City, Galveston controlled the entire commerce of the State; purchasing all that was sold, selling all that was bought, and levying tribute on nearly every business transaction within its borders. Little did it matter that the gateway to the sea was blockaded by sand bars—which exacted an additional tribute from the producers and consumers of the State to cover the cost of the lighterage charges, for there was no competition to divert the traffic; prices generally were high, and there was enough for all and to spare.

These were the days which made for Galveston the nineteen millionaires attributed to this little city of thirty thousand people in the New York *Tribune's* list of American millionaires.

But the conditions changed as the bonds were broken, when their richest territory was tapped by the railroads from the northern and eastern cities. Then began a period of active competition for the commerce of the State, which had been so profitable to Galveston. The activity of this competition, and the consequent reduction in profits, have saddened the last years of that earlier generation of Galvestonians which now is rapidly passing away. But their sons have adapted themselves to the new conditions, and are making their presence felt in the Southwestern commercial world. To them belongs the credit of enlist-

* Manuscript received December 7, 1896.—*Secretary, Ass'n of Eng. Socs.*

ing the co-operation of the progressive spirits of the great Western States in a united effort towards interesting the United States Government in the great work of improving the entrance to their beautiful harbor.

The people of Kansas and Colorado, chafing under the alleged extortionate charges of their rail outlets to the Atlantic seaboard, quickly responded to the appeal, and through their representation in Congress induced the Government to undertake the work of removing the bars at the entrance to Galveston harbor.

Along the entire line of the Louisiana and Texas coast, from the mouth of the Mississippi to the Rio Grande, there was nothing to compare with the land-locked harbor of 451 acres comprising Galveston Bay, and there has never been any division of opinion among the United States engineers as to the wisdom of deepening the entrance to this inviting harbor, capable of floating the navies of the entire world.

Between the northeast end of Galveston Island, and what is known as Bolivar Point—a peninsula extending southward from the main land—is the principal outlet for the waters of Galveston Bay. It is about three miles across from shore to shore, and through this channel ebb and flow the tides from the Gulf of Mexico, which, meeting the littoral currents which flow generally in a southwestern direction along the coast, deposit the sands which they carry and form what is known as the outer bar to Galveston Harbor; it is about four and one-half miles out from the shore. This it is which interfered so seriously with navigation.

The $77,000 expended prior to 1874 was wasted in a fruitless effort to deepen the channel by means of dredging, and when operations of this character were finally suspended, the natural depth of 12 feet over the outer bar at mean low tide and 13 feet over the inner bar had not been increased.

Then it was—in January, 1874—that the Board of Army Engineers adopted the famous Gabionade project, which contemplated the construction of two gabionades, or training walls, for the ebb and flood tides; the one, from Bolivar Point seaward, on the north side of the channel to the outer bar, and the other from the extreme northeasterly end of Galveston Island along the south side of the channel, in a direction generally parallel with the north gabionade, extending out from the mainland at Bolivar Point.

Since the failure of the gabionade project these sea walls have been known as the north and south jetties, respectively.

The Board of Engineers seemed to have been in doubt as to the proper height, distance apart and length of these two gabionades. They were to be training-walls for the under-currents which they theorized were the cutting agents on which they must depend for the deepening of the channel, but were not to materially interfere with the extraordinary ebb floods which at times occur in this region with such disas-

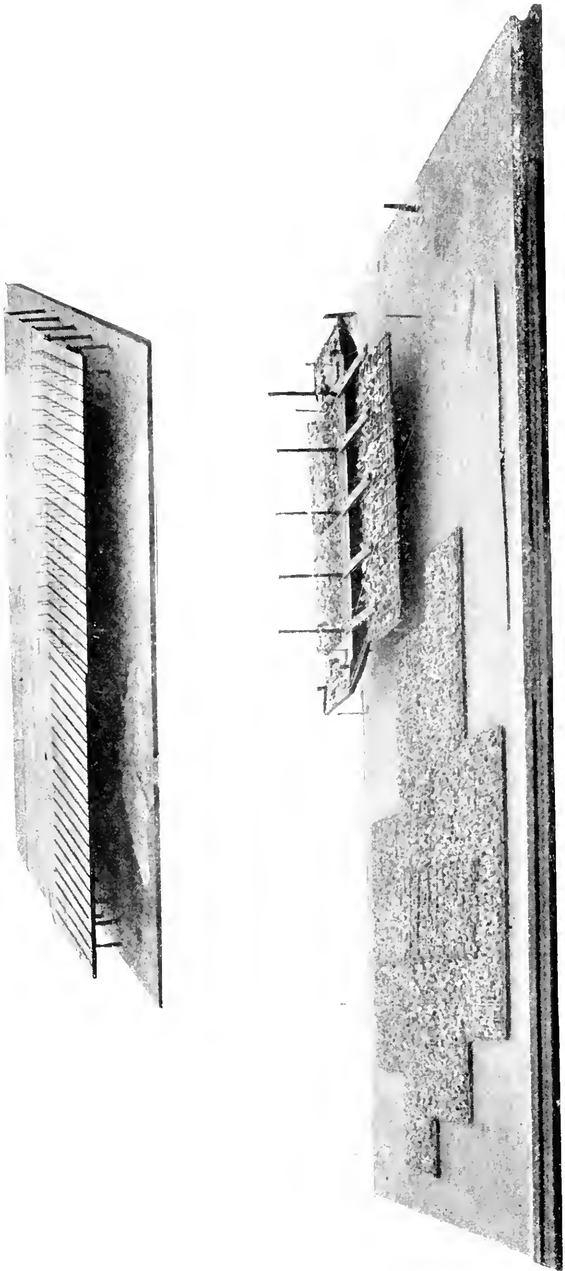


FIG. 1. MODELS FOR WORLD'S FAIR, SHOWING MATTRESS OPERATIONS.

trous consequences to the improvements on Galveston Island, and cause the waters of the bay and the waters of the Gulf of Mexico to meet in the streets of the city. In the storm of 1875 the general level of the sea at Bolivar Point was $8\frac{1}{10}$ feet above mean low tide, while the waters were said to have been banked up at the upper end of the bay to a height of 12 to 15 feet, caused by a stiff ten-days' blow from seaward. The damage was done when the wind shifted suddenly to the north and blew a gale, driving the waters over and around the island into the gulf.

These training-walls were not necessarily to rise above the surface

Fig. 2. The South Jetty of Sandstone.

to accomplish the purpose for which they were intended. They were expected more especially to arrest the sands which are carried along the coast by the littoral currents, and to prevent the deposits in the line of navigation. The area of cross-section between Bolivar Point and the end of Galveston Island was 155,611 square feet. The hydraulic mean depth was $17\frac{3}{10}$ feet, and the maximum depth was 42 feet. The mean daily tide at Bolivar Point is one and one tenth feet.

Each jetty-wall was to consist of two rows of gabions, parallel and adjoining, and laid on willow mats resting on the sand. The mats were placed in position by divers and weighed down with concrete blocks

weighing about two hundred and thirty pounds each. The gabionade was built between two rows of guide piling, and the filling with sand was done after the gabions were placed in position. A gabion was nothing more nor less than a woven pine stake-box, 6′ x 6′ x 12′, coated with cement inside and out and filled with sand, using larger size gabions for the deeper water.

The work done during the first season was largely destroyed by the great storm of 1875, and the gabions were badly broken and displaced. The Board of Army Engineers again convened to decide whether the gabionade system was a failure or not. The records show that after

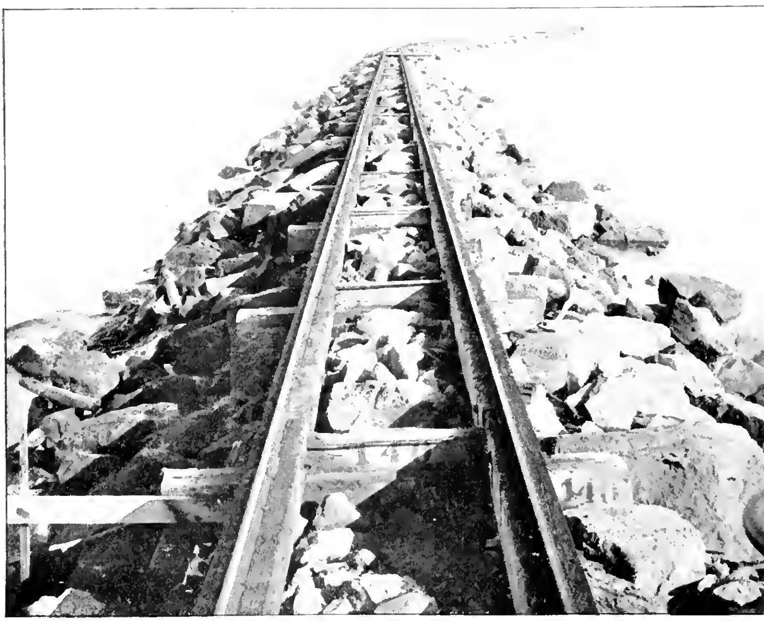


FIG. 3. THE SOUTH JETTY, 14,000 FEET FROM SHORE.

making minor modifications in the plans it was decided that the project should be carried on, and that it was so done until 1879, when the Board of Engineers convened once more for the purpose of passing upon the results attained after 7,332 feet of the outer end of the north jetty had been built and some considerable portion of the inner ends of both north and south jetties. It was decided that, so far as the outer bar was concerned, the gabion plan was a failure, as no satisfactory results had been accomplished. The channel over the outer bar was no deeper; the moving sands carried by the littoral currents had not been arrested, and the gabionade itself was in very bad condition.

So (November 28, 1879) operations on the gabionade plan were permanently suspended, after having built 9,606 feet of gabionade in the north jetty and a considerably less amount in the south jetty.

At this time we wonder why the engineers should have expected an increased depth over the bar without a training-wall on both sides of the channel, especially when the depth on the inner bar, where the waters had been confined, had increased from 13 feet up to 20 feet. It is likely, however, that the real reason for suspending operations on the gabionade was because of the unstable and unsubstantial character of the gabions themselves. It seemed impossible to keep them in position;

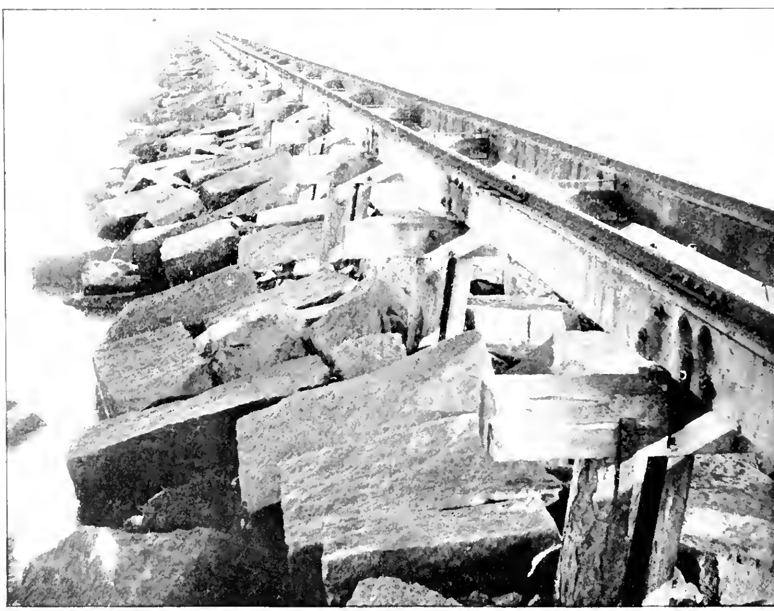


Fig. 4. The South Jetty; A Finished Section.
Sandstone Core-Granite Cover.

the storms broke them open and washed out the sand filling, demonstrating the unwisdom of battling with the seas with structures so frail in construction. One curious feature of this experimental work was the fact that the gabions resting on mats seemed to sink into the sand as rapidly as those without, the settling of the gabions ranging from 3 to 7 feet. Another unpleasant surprise was caused by the failure of the gabionade to cover itself with the drifting sands, as was fully expected, and which, in fact, was the vital feature of the gabionade project.

During the entire period of the writer's operations in Galveston Harbor, in 1892 and 1893, he failed to observe a single trace of the existence of any portion of these famous gabionades; and were it not for the statements of history and the Government's increased charges against the improvement from $70,000 in 1874, when dredging operations were abandoned, up to $600,000 in 1879, when the gabionade project was permanently abandoned, one would hardly believe that such operations had ever been carried on there.

Once more the Board of Engineers convened, and the willow-mattress project was the result. The Colonel of Engineers in charge

Fig. 5. The South Jetty. Placing the Granite Blocks.

said in his report: "It is now intended to build the jetties of brush and stone on a system which will undoubtedly succeed, for it has been applied to open sea exposure at the mouth of the Maas, where it has realized all anticipations and established a certain and economical way of constructing these sea works on sand coasts."

The top of the jetty was to be five feet below the level of mean low tide; twelve feet wide for first 4,080 feet; then gradually sloping up to the surface, with the top width increasing up to twenty-four feet, at a distance of 10,220 feet from the shore; from thence on with a uniform width of twenty-four feet on top to a point 14,960 feet from the shore, where

began the end slope, 370 feet long, downward to the bottom. The gabionade project was figured to secure 18 feet of water; the mattress project 25 feet, and the later project, which is the one being carried on to-day, is expected to produce a channel of 30 feet.

As soon as the mattress project was decided upon, Congress was asked for an appropriation of $500,000, and operations under the new project were vigorously carried on until 1886; but the work was confined to the south jetty, which was practically completed to the outer edge of the bar. The north jetty was left untouched and, naturally enough, there was no increased depth of water on the bars by reason of the operations during

FIG. 6. THE SOUTH JETTY. FIVE DERRICKS AT WORK PLACING GRANITE COVER.

these six years, although a large amount of money had been expended, including a donation of $100,000 from the City of Galveston.

At this time it was noticed that the mattress jetty was sinking and disappearing, and a line of levels run over the top of it showed a profile ragged and broken. Closer investigation revealed the fact that the rapacious sea worm—the *Teredo Navalis*—was rapidly eating up the brush-work of the entire jetty. The danger of this seemed never to have been thought of. In 1892 and 1893, like the famous gabionades, there was little to indicate that such a thing as a completed mattress jetty had ever existed.

Again the Board of Engineers convened, and the present project, consisting of two practically parallel solid-rock jetties, was adopted. The surface of the jetties was to rise to a height of 5 feet above mean low tide, to be 12 feet wide on top, with natural slopes. The outer ends of the finished jetties were to be in 30 feet of water and 7,000 feet apart. The general lines of the gabionade and mattress jetties were to be followed. Excepting near the shore end of the south jetty—where the wall consisted exclusively of sandstone—the core of the jetty was to be of sandstone and the covering of top and slopes of granite blocks, increasing gradually in size from three-quarters of a ton at the shore end up to

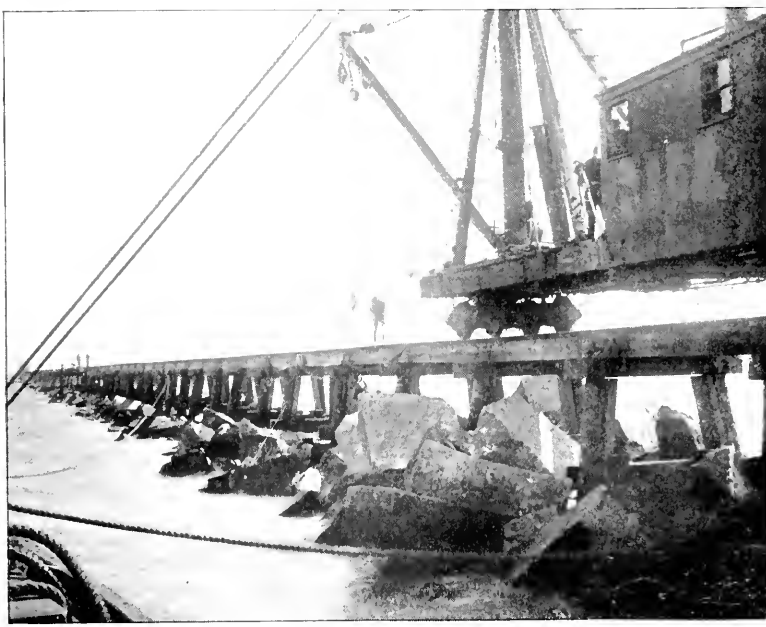


Fig. 7. The Extreme End of South Jetty in 1893. Pile Driver and Car Derrick at Work.

not less than ten tons, nor more than fifteen tons at the outer end. Sandstone was specified to weigh not less than 140 pounds to the cubic foot.

In accordance with these plans, the work of jetty building was again begun, and for ten years has been carried on at a speed depending upon the liberality of the appropriations. At first the various portions of the work were handled by separate contracts, the extent of which was limited by the appropriations; but later the improvement was placed on the Sundry Civil list and a contract for the entire work was authorized

and made. Under this contract the work for a number of years has been carried on at a cost of about one million dollars per annum. On June 30, 1895, the Chief of Engineers reported the total charges against Galveston Harbor as aggregating $5,590,970.40, and the estimate of amount needed to complete the project to be $1,700,000, making a total of nearly $7,300,000. Under active competition at the time of the letting of the present contract, the Government secured low prices, as follows, viz., $2.35 per ton for sandstone in place in the jetty wall, and $4.10 to $4.40 per ton (depending on the size) for the granite blocks. Sandstone had to be hauled 150 miles and the granite about 250 miles.

In the prosecution of work under this contract, the successful contractors early discovered a very serious mistake they had made of guaranteeing to furnish sandstone weighing 140 pounds to the cubic foot, when much of the Texas sandstone weighed but 128 pounds. It developed that it was practically impossible to carry out the contract. A mutual concession of ten pounds in weight for ten cents in price to a large extent overcame the difficulties at a sacrifice to the contractor of practically all the profit on the sandstone portion of the work.

At the end of the fiscal year, June 30, 1895, the south jetty had been extended seaward 32,829 feet, with all but 829 feet entirely completed and 5,100 feet of additional extension yet to make, while the north jetty had been built 22,500 feet seaward, with 4,000 feet incomplete. It will be noticed that the south jetty is about 10,000 feet longer than the north jetty. The most of this difference is due to a long shore connection over the low-lands at the extreme northeast end of Galveston Island, and running in a general direction parallel with the coast instead of out to seaward.

As a direct result of these operations, the depth of water on the outer bar was increased from 12 feet—the natural depth—to 14½ feet June 30, 1894, and to 17¾ feet June 30, 1895. Unofficially, the writer learns that it is now about 20 feet at mean low tide.

Meanwhile, the inner bar has practically disappeared, there being 24½ feet of water there June 30, 1894.

Although the jetties were gradually increasing the depth on the outer bar, it was decided some two years ago to supplement their work by dredging operations with a very powerful suction dredge, and a boat was built by the Government expressly for this purpose, and has since been put to work with very satisfactory results, as reported. Meanwhile, the jetty-walls are being pushed seaward to the 30-foot contour line, where they will stop. Whether the 30-foot contour will move further out with the diversion of the littoral currents to seaward, remains to be seen. The writer is inclined to believe that such will be the result, and that the jetties must eventually be extended still farther seaward, though the movement will likely be very slow.

Although there has been some settling of the stone jetties already constructed, necessitating moderate repairs, yet there is every evidence that the fourth project formally adopted by the Board of Army Engineers will be a pronounced success, even if the first three were complete and costly failures. It will provide at least 25—and with the aid of the powerful dredge-boat probably 30—feet of water where naturally there was but 12 feet over the outer bar.

The cost of the work will have been excessive, due to the enormous amount of experimental work. But the advantages resulting to the people of Kansas, Colorado, Oklahoma, Indian Territory, Arkansas and Texas of deep water at Galveston will many times repay even this excessive cost.

The commerce of the port of Galveston has increased from 863,196 tons in and out in 1877 to 1,211,354 tons in 1882 and 1,452,832 tons in 1895.

You, who were at the World's Fair, will perhaps remember the models exhibited there, illustrating the methods of the third or brush-mattress project. In Fig. 1 you have a view of these models, showing in a general way how these mattresses were built, floated to position, sunk into place on the sea bottom and weighted down with broken stone. The shore end of the south jetty appears in the back ground. Fig. 2 is a view of the south jetty at a point 9,000 feet from the island, and where the deflection to seaward is made. Fig. 3 gives a good view of the awkward curves introduced into the south jetty, and shows plainly the method of constructing the railway built on this jetty wall for the purpose of delivering materials. Figs. 1 and 3 show that portion of the south jetty, which is built entirely of sandstone.

Fig. 4 shows the finished jetty and the granite blocks after they have been placed in position with a derrick. Fig. 5 represents one of the large derricks at work placing a block of granite, with a train on the trestle in the background. Fig. 6 is a view of four derricks on the two barges and a track derrick, all at work placing granite blocks and putting the finishing touches on the jetty. Fig. 7 shows the granite blocks piled roughly on the jetty, after being unloaded from the flat cars which brought them from the quarry, and also the end of the jetty with the piledriver, driving two piles in a bent in the distance, advancing the trestle work ahead of the jetty, and the car derrick at work in the foreground. Fig. 8 is a general map of the entrance to Galveston Harbor.

The work on the north jetty was begun and carried on for some time in practically the same manner. There being no railroad on Bolivar Peninsula at that time, a car ferry was established and the trains of rock brought over from the railway yards of Galveston. This method,

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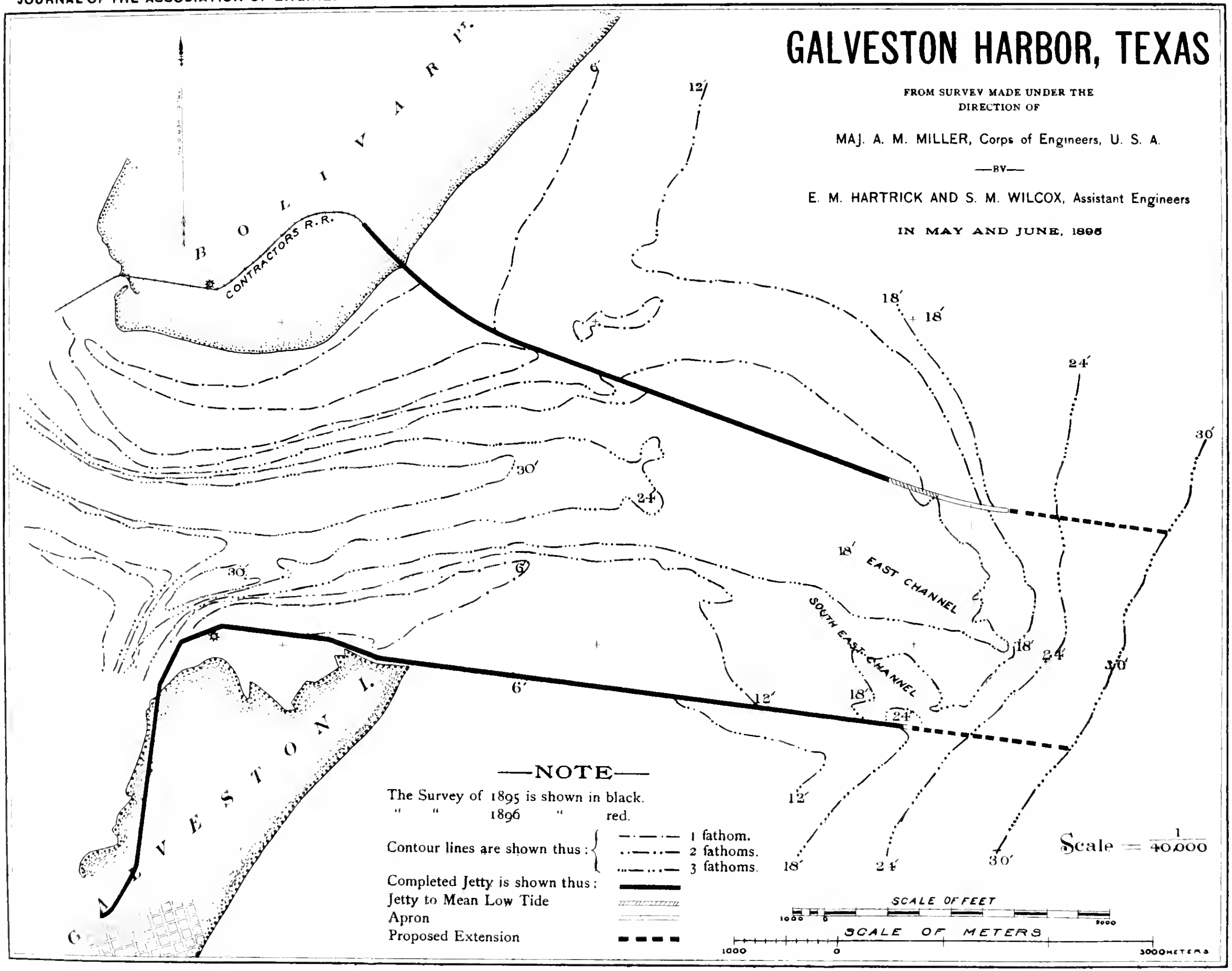
however, proving slow and expensive, it was supplemented by a barge line, which was established to a point on the mainland, near Houston, and deliveries of rock made directly into the jetty. With the aid of the barge line the work has progressed rapidly, and if the Government continues the appropriations at the rate of a million dollars per annum, we may hope ere long to read the announcement that this mammoth undertaking is finally completed, and that the Port of Galveston can be entered by any ship which floats.


GALVESTON HARBOR, TEXAS
FROM SURVEY MADE UNDER THE DIRECTION OF
MAJ. A. M. MILLER, Corps of Engineers, U. S. A.
—BY—
E. M. HARTRICK AND S. M. WILCOX, Assistant Engineers
IN MAY AND JUNE, 1896
BOLIVAR PT.
CONTRACTORS R.R.
GALVESTON I.
EAST CHANNEL
SOUTH EAST CHANNEL
6′
12′
18′
24′
30′
—NOTE—
The Survey of 1895 is shown in black.
" " 1896 " red.
Contour lines are shown thus: 1 fathom. 2 fathoms. 3 fathoms.
Completed Jetty is shown thus:
Jetty to Mean Low Tide
Apron
Proposed Extension
Scale = 1/40,000
SCALE OF FEET
SCALE OF METERS
1000 0 3000 METERS

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STRUCTURAL STRENGTH OF SHIPS AND IMPROVED ARRANGEMENTS FOR REPAIRING THEM WITHOUT DIMINUTION OF THEIR STRENGTH.

By Joseph R. Oldham, N. A. and M. E., Member of the Civil Engineers' Club of Cleveland.

[Read before the Club, November 10, 1896.*]

In the commercial world it appears to have become an established conviction that dividends cannot now be increased by leaps and bounds, as was the case some years ago; consequently the merchants, manufacturers and shipowners of to-day seem to concentrate their energies upon the perfecting of details connected with the handling or transportation of their merchandise, upon improvements of their plant, or upon a reduction in certain items of expenditure of which, but a few years since, only very casual notice was taken. With shipowners, the tendency is to largely increase the capacity of vessels so as to carry greater dead-weight in units of displacement and with but a small increase in working expenses. The science and practice of engineering have become so perfect and their secrets so widely known, that no very large advantage can be secured by one efficient and painstaking engineer over another through any radical departure in design or in the general system of construction applicable to similar structures. Our *marine* engineers and shipbuilders are similarly circumstanced, and those who are actuated by the laudable desire to be second to none, find their safest course towards pre-eminence in the careful study of details of construction, by which means a sure though small advantage, slowly acquired, may be secured over less thoughtful and less methodical competitors.

The first iron steamboat ever built was launched in the year 1821. The oldest steamer now in active service in the world, however, is afloat on lake Erie, the United States Steamer "Michigan," which was built at the city of Erie on this lake, in the year 1844. That was before the celebrated "Great Britain" had crossed the ocean, and in the same year that the first Cunard steamship made her initial trip to Boston.

During the last fiscal year 108,782 tons of shipping was built on these lakes. Such an output of steel tonnage has never before been made on the banks of the unsalted seas. Indeed, this is nearly equal to two-thirds of the tonnage constructed on the River Wear during the last nine months, and I may remind you that Sunderland is the greatest shipbuilding port in the world. This year's output there will be fully 230,000 tons.

* Manuscript received December 14, 1896.—*Secretary, Ass'n of Eng. Socs.*

Our steel tonnage has been increased fully 40 per cent. since 1893. The capacity of the vessels built on these lakes this year is 86 per cent. larger than that of those built three years ago. On the ocean, however, vessels have recently been constructed to carry 13,000 gross tons.

STRENGTH OF SHIPS.

Professor Mosely says that the strongest form that can be given to a solid body, in the formation of which a given quantity of material is to be used and to which the strain is to be applied under given circumstances, is that form which renders it equally liable to rupture at every point, so that when, by increasing the strain to its utmost limit the solid is brought into a state bordering upon rupture at any one point, it may be in the state bordering upon rupture at every other point. Moreover, the strongest form is also the form securing the greatest economy of material.

As to the structural strength of ships. It is not unusual to find strain existing in the side plating butts below the upper deck and in the bilge plating butts above the bottom while the upper shear strakes, deck stringer plates, keel and bottom plates show no signs of distress. Now such straining could not be caused by longitudinal bending, because stress due to bending moment is a maximum on the upper stringer and shear strakes and at the keel and lower bottom plating alternately. The distress at the upper turn of the bilge might be attributed to transverse bending as the break in the framing above the upper bottom is an element of transverse weakness, but there is no such discontinuity of strength between the upper deck and the side plating. From this it appears that such signs of straining as those just indicated could not be caused by longitudinal bending alone. When it is understood, however, that longitudinal shearing stress generates equal shearing stress in a transverse direction, the distress frequently observable on the sides well above the bottom and near the neutral axis, and below the upper decks, in ships having great longitudinal strength, may not be so difficult to explain. The late Prof. Jenkins pointed out that in the case of a body subject to bending moment as well as to shearing stress, the distribution of shearing stress differs materially from that in the case of a body subject to shearing stress only. In this he is in accord with Rankine, who showed that a shearing stress, when combined with a bending stress, is not uniform over the section, but is greatest at the neutral plane and least at the top and bottom. The excess of the maximum shearing stress over the mean depends upon the arrangement of the material in the section. On the contrary, the longitudinal bending moment is a maximum at the top and bottom and nil at the neutral axis. If the truth of these statements requires confirmation, such may

be found in the fact that in steel shafts, disintegration begins at the center, and gradually spreads until it reaches the surface, when fracture occurs without warning. Of course it will not be assumed from this that the structure of a floating body is free from stress along the neutral plane, for such cannot be the case, as besides a vertical longitudinal, there is also a horizontal transverse bending moment, which produces maximum stresses at the longitudinal neutral plane. But of more importance than this is the stress due to shearing moment, which, as I have said, is maximum where stress due to longitudinal bending moment is nil. In addition, the force of the waves has to be resisted at all parts of the external surface of the hull.

Sir William Fairbairn established the practice of the mathematical investigation into the strength of a ship considered as a hollow girder so far as longitudinal bending moment is concerned. The principle is the same as that by which the strength of a beam may be calculated.

It follows, therefore, that the sum of the products of the small elements composing the section of a ship, such as keel plates, stringer plates and the effective area of steel hatches, multiplied by the squares of their respective distances from the neutral axis, will constitute the moment of strength of the entire section. The principles generally governing the strength of beams or girders enable us to compare the relative importance of any assemblage of plates and bars such as are commonly selected to form the structure of a modern steel ship.

STRAINING OF SHIPS.

Mr. Fairbairn assumed that ships, whether afloat or grounded on a rock, are governed by the same laws of strain as simple-built beams, such as tubular bridges. Under certain test conditions he investigated the longitudinal strength of an actual vessel, and advocated plating over the upper deck beams, so as to make the section of iron at the deck equal to the section at the bottom. If this could be attained one of the greatest troubles of the naval architect would cease to exist; but, as the requirements of loading and unloading lake steamers now are, the shipbuilder has a complicated task on his hands. Not only are the hatchways required to be extremely large, but greater loads are demanded on almost the same draft of water as existed when cargoes of half the weight now carried were deemed satisfactory. If we consider a ship in her upright position when afloat or poised on the rocks with the water partially ebbed away, she may be looked upon as a hollow girder, and as such, if it were possible, her transverse mid-section would by preference be formed with a solid deck, making the top and bottom flanges equal. But the actual conditions require the solid deck

to be reduced for hatchways. Now, without doubling the thickness of the upper deck side plating and otherwise adding strength to make up for the large portion of the decks cut away for the hatchways, and amounting to about 65 per cent. of the total breadth of the deck plating, the longitudinal strength of the symmetrical girder, as compared with the perforated girder, is as 600 is to 325. A ship may in some respects be looked upon as a loaded girder, but the stresses to which she is subject are much more complicated. A vertical flange in a bridge remains vertical, but a vertical flange in a ship on the stocks may become horizontal, or nearly so, when she is working in a seaway. Moreover, one side of a vessel may be in tension above water at one moment and be in compression under water at the next moment. May not this account for the straining of butts in the locality of the neutral axis, and for the fracture of plates at a considerable distance from the gunwale or top flange?

MOMENT OF INERTIA.

I have calculated the moment of inertia of a modern steel lake steamer at her midship transverse section. I also show the stress per square inch to which she would be subject without steel hatches. You will observe that with the latter her neutral plane is greatly raised. This is very desirable, for the average lake steamer has her neutral axis much too low. I will proceed on the assumption that the longitudinal bending moment of a ship afloat is greatest when crossing waves of her own length, and at the instant when the crest is amidships, the weight and buoyancy being equal. The principal dimensions of the steamer investigated are:

Length on water line	400	feet.
Breadth moulded	48	"
Depth, total without hatches (as a girder)	27.8	"
" " with steel hatches	29.1	"
Displacement at 17 feet mean draft of water	= 7,400 gross tons.	
Half moment of inertia	= 65,034	

As the weight and distribution of cargo in our steamers is so varied it would hardly be justifiable in this instance to spend the time required to calculate the exact bending moment with an ideal cargo. So, in order to obtain this, I will take a coefficient as a fraction of the weight (W tons) into the length (L feet) to obtain the bending moment. Annexed will be found the divisor for bending moments of seven steamers. Maximum bending moment $= W \times L$ divided by one of the following numbers:

Hogging on wave crest.	Sagging in wave hollow.
24.4	117.
29.9	91.8
37.	83.
37.	43.
36.	50.6
37.6	39.7
27.8	55.7
32.79 = mean.	68.68 = mean.

The following is the moment of a well-deck tramp, 290×38 and 3,590 tons displacement: $\frac{3{,}590 \times 290}{80} = 13{,}000$. From this it appears that her maximum bending moment equals 13,000 foot-tons. As lake steamers are more severely loaded and float much closer to the bottom than ocean vessels, I use 50 as the divisor for ascertaining the bending moment.* Then the coefficient of the steamer illustrated $= \frac{59{,}200 \times 18.78}{130{,}068} = 8.54$ tons tension per square inch of section at gunwale, and $\frac{59{,}200 \times 10.32}{130{,}068} = 4.62$ tons compression on the bottom. These are the stresses with steel hatches. Without steel hatches the top sides are much more severely stressed. Thus $\frac{59{,}200 \times 19.7}{121{,}604.2} = 9.332$ and $\frac{59{,}200 \times 9.33}{121{,}604.2} = 4.542$ tons per square inch on bottom. Without hatches the neutral plane is 19.17 feet below the gunwale. With steel hatches this distance is reduced to 18.78, and this causes the discrepancy between the stress on top and bottom of the girder to be largely reduced.

The moment of inertia, based on the transverse mid-section and the bending moment due to the maximum load when the vessel is afloat in the largest seaway, should be calculated for every new design.

IMPROVED HATCHES.

I can see no necessity for increasing the strength of the bottom; for, as ships are generally constructed with double bottoms, the bottom is the strongest of the four cardinal surfaces; and, in most ships, the top or deck is the weakest. Therefore my present efforts with regard to structural strength have been concentrated upon the upper deck, with a view to compensate for the immense openings cut therein for hatchways. The common oak hatches or "hatch covers," as they are sometimes called, do not contribute in the slightest degree to resist the tensile stress due to hogging moments; but the steel hatches I have designed, even though very thin, will largely resist the stresses resulting from either hogging or sagging forces.

I will ask you to permit a digression while I describe certain anomalies connected with naval architecture, and which I am led to believe are not confined to ships alone, but may be discovered among the exceptions to be found in other large mechanical structures. I refer to flimsy examples of naval architecture which some of us may have sailed on, with or without the knowledge of the fact. As you are aware, most modern ships are constructed more or less in accordance with certain

* Bending moment at mid length $= \frac{7400 \times 400}{50} = 59{,}200$ foot-tons.

rules formulated and tabulated by the great ship classification societies. Some of these rules are very valuable and reliable, and, when faithfully adhered to, they will produce a strong and seaworthy ship, but, even then, the production will, I fear, fall short of that ideal structure, the dream of the shipbuilder and the vision of the shipowner, wherein the maximum of strength will be found closely associated with the minimum of weight.

USEFUL WEAK SHIPS.

The above title may sound paradoxical, and indeed the pre-eminence of such vessels as dead-weight carriers does not exactly result from their weakness, but from the contributing cause, viz: their lightness or lack of scantlings. Permit me to say however, that a weak structure may not be light and a light structure may not be weak. Such ships as I refer to—and I can call to mind several of them—are by no means peculiar to these lakes nor are they confined to any nationality. Every great maritime nation has one or more of them. They are generally the product of economical experiments unconsciously made. They were built regardless of now well-known scientific principles and reached their present stage only after many years of trying to do without something. Those useful ships, such as the "Michigan," the "John Bowes," or the "Tiber," which are afloat to-day, represent the "survival of the fittest." For instance, where the text-books say that $\frac{10}{16}$ is required, they have only $\frac{8}{16}$; where the rules require triple or double riveted butts, these flimsy structures have only two rows, and, in many cases, only a single row of rivets; though their scantlings correspond to easy proportions, their ratio of length to depth is comparatively extreme. In fact, they were built according to that slow but sometimes sure practice known as the rule of thumb. A word about this rule—if I may give it such a title. I have known men, and many of you know them too, who were born engineers or shipbuilders, and, instead of calling their guide the "rule of thumb," I would say that they act from an experimental knowledge, which became reliable as they became exact, which became comprehensive as they became experienced, and which became more useful as they became more cautious.

It must not be supposed from this that I undervalue the study of scientific works, or that I think lightly of text-books or books of rules; by no means. A man's practical experience, even though he be a great genius, such as Robert Stephenson or James Watt, is necessarily limited, and in the work he may do (though it be very useful and valuable), it can guide him only to a very limited extent. His knowledge may be intuitive, but his designs must be circumscribed and imitative. Only a scientific engineer could have projected and designed a "Great Eastern," which was ten times as large as any of her predecessors.

A safe Tay bridge could not have been constructed with anything like its symmetry and lightness without the aid of scientific knowledge and formulæ. The point I desire to make here is only this—that when we come to a complicated composite structure, such as a large steamship, our books do not show us how to make them with a certain amount of material so that any one part will be as liable to rupture as any other; but this is sometimes accomplished by unscientific mechanics after a long experience in constructing works of similar design. For instance; in our ships, constructed according to modern rules, the upper deck stringer plates and angle-bars have sometime no factor of safety, while other parts, such as the bottom and portions of the sides, have a factor of five or six. Our boiler shells have a factor of about six, the furnaces and fire-boxes frequently have no factor. So, with many of our modern ships, there is an excessive factor in many places in spite of our boasted knowledge, whilst some modest, practical old shipbuilders have floating monuments on the great seas to-day which prove by their existence that they have a factor of safety, and by their dead-weight that there is in them little or no waste of material. They are beautifully simple; and, as you know, simplicity, in all things, but proverbially in mechanics, is supreme excellence. This should indicate that some of the elements composing the structure of a ship are heavier than necessary, and, notwithstanding years of experience—the results of which are tabulated from innumerable examples of carefully-designed ships—it is quite evident that there is a large redundancy of strength in many parts of our modern steamers. Of course, there would be but little loss in such cases were it not for the extra weight and cost invariably associated with such local excess.

When a steamer is heavier either in hull or equipment than the work she has to do warrants, such superfluous weight will handicap her as long as she floats.

To bring this nearer home, I may say that there are old steamers afloat on these lakes and of moderate depth, too, the top-sides and upper decks of which are so poorly connected and largely perforated as to make a shipbuilder wonder how they ever got across Lake Erie, whereas they have not only crossed this little lake, but have done good work over all these dark and stormy waters for more than twenty years. But these vessels have main decks as well as light upper decks, and on that point I would like to say a few words. It has been stated, and the statement appears for the immediate present to have been confirmed by practice, that a main deck is useless unless required for carrying cargo. Now, though I readily admit that one of its greatest uses in a broad, shallow steamer is to support such weight, it is also of special value, at least in an ore-carrier with its weak upper deck, to strengthen the hull horizon-

tally and transversely, though it may not contribute largely to its strength in resisting bending moment. Moreover, a good main deck not only strengthens the beams by forming a broad top flange, but it also relieves the beams of a great portion of their work, which is to resist panting. Though such a deck may not always be required to carry cargo, the strength of a second deck is invariably required to support the sides of long vessels when the depth of hold is about twenty feet or over. Of course, beams can be made so strong and so well braced that a main deck may be dispensed with. Such beams, however, should partake of the box-girder form; but then, with the weight of stringers and ties, this arrangement would approximate to the weight of an average main deck.

OCEAN AND LAKE VESSELS.

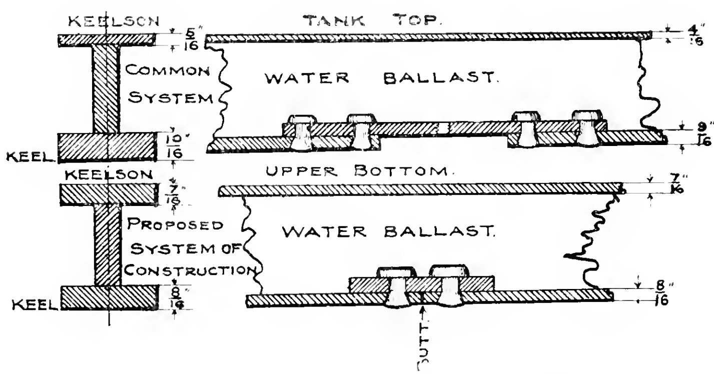
Speaking generally and comparatively, I would say that, while the bottom of ocean steamers should be made for floating, the bottom of lake vessels should be designed for grounding. The practice of lapping plates, instead of butting them, has somewhat recently become popular on these lakes. The system is by no means new, however, as Messrs. Harland & Wolf, of Belfast, adopted it about ten years ago. But, long before they had thought of this means of doing away with the necessity of calking and recalking bottoms and bilge butts to destruction, Mr. John Reid, of Port Glasgow, carried this system into practical effect on the old "Tiber," built about forty years ago, and she was as good an old vessel as I ever examined. But lap joints are not so good, according to my experience and judgment, for the bottom of lake steamers or for the sheer strakes and stringer plates of large vessels. No riveted joint can be stronger than a properly designed double strapped butt joint, though such joints are expensive.

When the strakes of plating are lapped over each other, packing or liners are necessary in order to make close and solid work with continuous fair transverse frames. The necessity of such liners is a serious and still common defect. Messrs. Wm. Doxford & Sons, of Sunderland, England, propose to avoid this by a well-known process called joggling. This innovation in modern ship construction is evidently appreciated by many shipbuilders, and it may be wise to adopt it in the construction of deep-water vessels, which seldom take the ground; but, for our lake trade, I think such a departure would only intensify that defect in ship construction which it seems most desirable to avoid, namely, the system of overlapping inside plates by a portion of outside ones, which makes it necessary to largely loosen and frequently to entirely remove one or more uninjured plates in order to replace an injured one.

Bottom lap joints, on account of the plate there being lower than

the remainder of the plate by its own thickness, receive the greatest stress when the bottom rests on the ground. Plate edges and the calking and riveting of the transverse joints are frequently cut or strained to destruction when the body of the plate is practically uninjured. I, therefore, propose connecting the bottom longitudinally and transversely by butt joints, which give a flush surface, so that all parts of the flat bottom may be equally stressed when the vessel grounds.

As the bottom plating will not be so heavy as bottoms now commonly constructed, I make the ballast tank top much heavier and stronger than is generally the case. For instance, the average thickness of the tank tops of ordinary steamers is about 65 per cent. of the thickness of the bottom plating. This system of construction I virtually transpose, making the bottom thickness no greater than the thickness of the tank top. This tank top is then stiffened and supported by transverse girders of suitable depth and thickness, say about 15



inches deep by $\frac{3}{8}$ inches thick, spaced about two feet apart in a medium-sized lake steamer, and riveted to the tank top in the ordinary manner, except that the fastening thereto will be increased to correspond with the increased thickness of the tank top plates. Underneath these transverse girders I fit longitudinal girders, about one to each strake of bottom plating, say four or five of such lower girders each side of the center vertical keelson plate, which runs from stem to stern or nearly so. These longitudinal girders, which extend down below the transverse or thwartship girders sufficiently deep to provide the proper capacity for water ballast—which will require to be about 40 inches deep in a large lake steamer—will be connected to the transverse girders by suitable fore-and-aft angle bars, or these plates may be flanged, and connected by vertical angle bars, the latter stopping several inches—say four or six—below the tank top or upper bottom, so that the upper bottom plates may not be pierced or seriously injured by the thrust of such

vertical angle bars, when the bottom strikes the ground. These bars may be continued down to the bottom plating or only to the horizontal angle bars which connect the longitudinal girders to the bottom plating. To secure sufficient transverse strength below the tank top, I fit peculiar diaphragm plates between each pair of fore-and-aft girders. These plates will be riveted by means of suitable angle bars or by flanging to the fore-and-aft girders, and to the bottom plating; and they will be comparatively lightly attached to the lower part of the thwartship girders, so that a thrust from the bottom may not fracture these girders. The diaphragm, having an opening or a man-hole in the lower part, will bend or buckle before the tank top could be fractured. Ballast tank tops, however thick they may be, will not long withstand the impact of large masses of ore falling upon them from a height of twenty feet or so without the protection of wood ceiling unless the butts and landings are well stiffened with vertical flanges and a double row of rivets. But with a tank top as thick as I propose, and properly supported, iron ore, coal and such cargoes may be thrown into the hold without fear of injury to the upper bottom. . . . Another reason why the bottoms of lake steamers should not be so thick as the upper bottom, is that groundings are so frequent and bottom plates require renewal so often that such plates are not permitted to remain in the ship sufficiently long to be dangerously weakened by corrosion.

The principal object of my invention is to do away with the lap joints, either longitudinally or transversely, in the bottom plating, for the full length of the cargo holds, and extending from end to end of the midship body of the vessel. Then, after leaving the flat of the bottom, the end plating may be lapped and double-riveted in the ordinary manner. It will be observed that with flush-jointed or edge-to-edge plating, I substitute single for double riveting except in the transverse or butt joints over the midship body; and, so far as tensile or compressive stresses due to longitudinal bending moment are concerned, double-riveted landing edges are not necessary anywhere.

I hope my design has mastered the evil, so far as the bottom is concerned. As regards the sides below the sheer strake, I think that joggling and lapping are all right, for the one tends towards a reduction in weight of hull and the other slightly reduces the cost of construction. I would like to say now that nowhere in the world can ship repairs be effected so quickly and economically as right here on these lakes.

COMPENSATION FOR HATCHWAYS.

In conclusion, let me briefly describe the improvements I propose for augmenting the strength of the upper flange of a ship girder and at the same time increasing the durability and resilience of the hatch covers.

My improved hatch coamings and hatches consist in fitting strong steel or metal hatches or hatchway covers, with angle bars at each side, which will embrace strong T beam or channel bar coamings, so as to increase the longitudinal strength of the decks and upper works, be more durable than the ordinary oak hatches and do away with the necessity for tarpaulins. When the hatchways are small, I make the hatches all in one piece, with the sides flanged down over the top of the coamings; or angle bars may be riveted at the sides, as with larger hatches. By preference, I hinge one side of the hatch to the coamings. The opposite side may then be lifted, by a rope or chain working through a block or pulley connected to the mast or to a post fitted for the purpose, till it reaches such an angle as to rest securely against such post or against a stanchion fixed to the deck; or the hatches may be held open by the chain, hook or catch, or be turned back onto the deck. When the hatchways are large, say over 30 x 8 feet, I make two, three or more pieces and join them by suitable hinges, so that they can be folded up transversely and be drawn to the port or starboard side, leaving the hatch open, or nearly open, according to the requirements of loading or unloading arrangements; or the hatches may be all in one length and be lifted by a suitable crane or by a tackle or chain attached through a block or pulley on the triantic stay at sufficient height for raising the hatches off the hatchways. With hinged hatches, angle or flat bars are fitted on the lower side in a fore-and-aft direction, to stiffen the plates and form a watertight joint when the hatches are closed, by means of rubber gasket or other suitable substance placed between the adjoining flanges; or the hatches may be fitted with suitable tie-rods and stanchions, similar to those commonly seen on the lower sides of railway cars, to keep them in shape and for lifting them off the hatchways and placing them in a convenient position on the decks. Asbestos, rubber or other suitable material may be used to make a perfectly watertight joint between the tops of the hatch coamings and the lower sides of the hatches. The hatches are secured to the coamings by suitable screw bolts and winged or lever nuts, or by common nuts. If the hatches are to be hauled to one side of the vessel, a suitable roller, of such a height as to raise one end of the hatch slightly off the coaming, is fitted in strong brackets to the deck.

A few years ago, tenders were invited for triplicate lake steamers. So far as general design and principal dimensions were concerned, these three vessels were alike, but when I compared them by their displacement, one was found to be eighty tons and another one hundred and fifty tons lighter than her sister ship. This discrepancy represents a maximum loss, in dead-weight ability, of about 7½ per cent. These steamers being constructed under my superintendence, it devolved upon

me to watch their performance for some time, and I may tell you that the results of frequent surveys tended to prove that the lightest of the three steamers was the strongest.

If the shipowners are not too exacting with regard to dead-weight cargo, and if the weights of material are not over-carefully scrutinized in the shipyard, it is by no means a difficult task to design and construct a strong ship.

On the other hand, if the designers are but sufficiently obtuse as to the exigencies of the trade for which the ship is intended, and provided the classification societies are a little accommodating or are not well informed as to the conditions of the work to be done by the vessel, a structurally light, weak ship may as easily be built.

But to produce a symmetrical structure, such as a large modern lake steamer, with a proper factor of safety and with the strength of the material so distributed that no one part of the structure will be more liable to fracture or straining than another, calls for the experienced training of the talented engineer, combined with the precision of the mathematician; for only under such conditions can huge, complicated machines be produced as quickly and economically as our times demand.

A FEW POINTS OF ENGINEERING INTEREST OBSERVED ON A SHORT TRIP ABROAD.

Pavements, Confined Rivers, and the Water Supply of Ancient Rome.*

By Francis W. Blackford, Member of the Montana Society of Civil Engineers.

[Read before the Club, November 14, 1896.†]

The limited time usually allotted to an engineer for travel and recreation often precludes the possibility of close study of engineering works. These conditions confronted the writer of this paper, and he presents to the society simply his observations, with the few details and technicalities that could be hastily gathered.

PAVEMENTS.

Unquestionably American city pavements suffer greatly in comparison with the modern pavements of London and Paris. Upon the busiest streets of both these great cities wooden blocks are in general use. Asphalt is used extensively for the narrower and less important streets, and stone blocks in many places, notably near the wharfs and in the wholesale districts. In the fashionable part of London, the west end, near and in St. James' and Regent's parks, well-kept macadam roads are used extensively.

All pavements are kept in excellent repair, and small gangs of workmen may be seen at almost any time repairing both the wood and the asphalt.

In the two cities mentioned the wooden pavements seem to be most in favor, and, from the best information that could be gathered, they seemed to be growing in favor with all classes, possibly the vehicle manufacturers excepted. By watching the work of repairing the wooden pavements of London and by conversing with the foreman in charge and with the superintendent of the Improved Wood Paving Company that lays and keeps in repair most of them, the following information was obtained: They are composed of blocks of Baltic pine from 6 to 10 inches long, 3 inches wide and 6 inches deep, laid or set upon a foundation of 6 inches of hydraulic cement concrete, the blocks having been first dipped in creosote oil. The top surface of the concrete base is made smooth by a covering or plaster of cement mortar, and after all

* For much of the information here given concerning aqueducts the writer is indebted to Dr. Russell Forbes, of Rome, and to his pamphlet upon the Roman aqueducts and fountains.

† Manuscript received December 15, 1896.—*Secretary, Ass'n of Eng. Socs.*

is thoroughly set, the blocks are placed directly upon the smooth surface of the concrete in rows across the line of traffic, leaving spaces of from $\frac{1}{4}$ to $\frac{3}{8}$ of an inch between the blocks. These spaces are then filled, or run in, with hot bituminous mastic, about one inch and the remainder filled with cement grout. The spacing of the blocks is maintained by three brads driven into the blocks to a shoulder. One row of blocks running lengthwise with the street is omitted at the curb until the swelling of the timber has ceased.

The timber is not thoroughly seasoned, neither is it green, but what is in England called first water timber, being that which is cut in the country tributary to the Baltic Sea during the winter season, shipped as soon as the ice is out of the harbors and probably marketed in about six months after cutting.

The dipping is not a forcing process, by which the creosote oil is forced into the pores, but a simple bath, the blocks not being in the oil more than two or three minutes.

The pavements last about eight years under very heavy traffic, and with lighter traffic much longer. Some that had been in for fifteen years were not in bad condition, and it has been known to last nineteen.

On the approaches to London bridge, where the traffic is the heaviest in the world, estimated at about 400 tons per foot of width per day, it actually wears out in about four years; notwithstanding this the approaches are paved with wood, which of itself is an evidence of its popularity. London bridge proper is paved with stone blocks similar to those used in this country. This is tolerated probably because there are no tenants along the side to be annoyed by the noise.

This character of pavement costs in London about seven shillings six pence ($1.80) per square yard exclusive of foundation, with a probable guaranty for about five years.

The success of this pavement is doubtless due to the care exercised in the selection and treating of the timber, and the careful manner of laying it, together with that requisite of any good pavement, an impervious and unyielding foundation.

On the busy streets of London small boys with shovel and basket gather up the horse droppings during the day and dump them into the sewer through standpipes at the curb line; and at night the entire street is washed down with a hose and scraped with a rubber scraper similar in principle to those used for cleaning plate-glass windows.

At intervals, fine gravel is sprinkled upon the pavement. This is soon driven into the blocks by the traffic, and is thought to increase the life of the pavement, and to better the foothold of the horses. It has the appearance of conglomerate or pudding stone when clean, and would not be recognized as wood unless closely examined. The omnibus traffic,

being both quick and heavy, is thought to be the most destructive to these pavements.

The popularity of this pavement is due not to its cheapness or its durability, but to its noiselessness. The din of the traffic of the Strand and other busy streets upon a cobble stone or well-worn granite block pavement, would be well-nigh intolerable to the occupants of the buildings, as well as to those upon the streets.

The wooden pavements of Paris are similar to those of London in appearance, and the construction seemed to be practically the same. They are swept with brooms throughout the day and thoroughly flooded and washed every night. During the day the accumulations are swept to the curb and washed into the sewer by water turned on from hydrants opening flush with the sidewalk, near the curb.

The blocks of the stone pavements of both London and Paris are larger than those usually laid in this country. They are generally well worn at the edges and correspondingly rough and noisy. Asphalt sidewalks of ample width are universal in Paris. They are kept scrupulously clean.

The curbstones in Paris and throughout Italy are universally very substantial, being about 8 inches thick, and joined together with a tongue and groove. The curb is flush with the sidewalk, a little rounded or battered, and 6 or 7 inches above the paving material. There are no crossing walks, but in Paris and London there are, in the middle of the street, many places of refuge that serve a useful purpose.

In Rome and Naples there is a great deal of stone paving composed of stone blocks, about 4 inches square, and 6 inches deep, set upon a foundation (apparently) of broken stone or sand. The blocks are fitted closely, with very small joints which are without filling. This pavement is quiet, for stone, and seems to stand the traffic very well. The traffic, however, is not heavy.

There are many very handsome pavements in Pisa and Florence, composed simply of blocks of marble, or limestone, about 18 x 24 inches superficial measurement, by 7 to 8 inches thick, carefully dressed, fitted together with joints not to exceed ¼ inch, and laid upon a broken stone and sand foundation. The roadway is symmetrical, with a crown of about 6 inches in a 40-foot roadway. The turns at the street corners are kept rough by stone cutters with the ordinary hammer and point. At other places, the smoothness of the stones does not seem to affect the footing of the horses. No one, of whom inquiry was made, could tell how long the pavements had been down, and no one could remember when any of the streets had been paved. Repairing was in progress, however, and some new blocks were being placed. In the middle ages Florence was an important seat of learning, art and wealth, and it is likely

that her streets were well improved as early as the fourteenth century. Probably the same kind of pavements seen there to-day were then in use.

In mentioning pavements in the reverse order of their age and construction, a few words about the Appian way, one of the oldest and probably the most notable of all ancient highways (called the queen of roads) will not be out of place. It was built by Appius Claudius about the year 312 B. C., and connected Rome with Padua and a number of cities lying to the south and west.

The first sight of it is somewhat disappointing, unless one knows what to expect, for the reason that the roadway proper is only 14 feet wide; there is, however, on each side, a sidewalk, 8 feet wide, which helps in some degree to restore the expected dignity.

The first two or three miles out of Rome are used as a modern highway, the original paving having been coverd with broken stone to make a smooth surface. The parts near Rome are not in ordinary use, but are kept open and preserved simply as a monument of antiquity. Only in a few places can the original paving be seen, most of it having been carried away by the dwellers in the Campagna and used for building stone fences and walls, and for other purposes. The curb stones, not being so easily removed, are in place throughout most of the way. The paving seemed to be of undressed limestone, or very hard and slippery basalt, laid flat, in irregular pieces of from 2 to 5 or 6 feet superficial area, and 6 or more inches thick. It is badly worn into ruts and very rough and uneven. The curb is of the same character of stone, and projects above the paving 6 or 8 inches. It had received some dressing with a hammer, but was not finely cut. The sidewalk was of the same general character of construction as the roadway.

The road is on high ground, and, for a distance of eight miles from Rome, and as much farther as the eye could follow it, probably six or seven miles, it is perfectly straight, with the exception of a slight detour, doubtless to avoid the three mounts supposed to have been built over the remains of the two Horatii, and three Curatii, who fell in combat before the assembled armies of Rome and Alba.

It was a custom with the Romans in those days, to inter persons of importance along the public highways. The Appian way, for a distance of eight miles, and perhaps much further, was lined on each side with tombs, some of which were doubtless of great magnificence. They have been sadly despoiled of all beauty, however, and, with the exception of the tomb of Cecelia Metella, which remains intact, have been entirely stripped of all decorations, and their marble covering. Nothing now remains but the brick and concrete core.

The paving of the Via Sacra, or Sacred way, in the Roman Forum, is similar to that just described. That in the streets of Pompeii is composed of large stones, but on the whole quite similar. It is very rough

and uneven, and much worn into ruts. Holes were pierced in the curb to serve as hitching places.

RIVER WALLS.

The substantial manner in which the rivers are confined, in their passage through the cities, would at once attract the attention of an engineer. This is particularly noticeable in Paris, Pisa, Florence and Rome, where the improvements of this character add greatly to the beauty of the districts near the river, transforming the space which is usually a mud flat, into a highway supported by massive walls, with a handsome coping, which serves as a rest for gaslights, statuary and other ornaments.

The walls at Paris, Pisa and Florence, do not exceed 30 feet in height above the ordinary winter stage of the water, but at Rome they are quite 45 feet, and built in the most substantial manner, the face stone being marble, carefully cut and laid in range courses, of considerable thickness, none being less than 15 inches.

The wall is built with a slight batter; and a foot-way, about four feet wide, is provided a few feet above the ordinary stage of the water. Stairways lead down at intervals, usually at the street crossings. Admittance could not be gained to the work which was in progress; but, from what could be seen, it seemed probable that the backing was composed of rubble masonry and concrete. The walls are built mostly in symmetrical curves, producing an effect very pleasing to the eye. This brings to my mind the argument often used against the levee system, as practised by the Government engineers to confine the water of the Mississippi, viz., that the bottom of the Tiber is now much higher than the valley adjacent, and as much as thirty feet higher than it was at the beginning of the Christian era, and that this condition was brought about by the levee system. This is certainly a mistake, for there are no visible evidences that the river is not cleaning its own bed; or that it was ever much lower than it is now. This opinion is strengthened by the fact that four or five feet of the water-way of the Cloaca Maxima was, in February of this year, visible above the surface of the water of the Tiber. This drain was built about the year 580 B. C., to drain the Roman Forum and adjacent territory, and it is said to have been the first application of the arch in Roman construction. It still performs its functions in a satisfactory manner, after having stood the vicissitudes of nearly twenty-five hundred years.

WATER SUPPLY.

To an engineer there is no more interesting study, in and about Rome, than the ancient water supply, and the remains of the aqueducts, which are everywhere to be seen in the southeastern part of the city, and in the country adjacent, for a distance of about seven miles in the

direction of the Alban hills. This stupendous work is worthy of the admiration of all beholders, and especially of the members of the engineering profession.

When the city had reached the zenith of its power and glory, no less than sixteen aqueducts, from six to sixty-one miles in length, and three branches, from two to three miles in length, had been built, and it then had a water supply estimated at 350 gallons per capita per day. It is better supplied with water to-day than any other city in the world, receiving daily, for each person, about three hundred gallons of clear, pure and palatable water.

The following table gives, in the chronological order of their construction, the total length of each aqueduct, the length of aqueduct supported on arches, and the date of construction, and conveys a faint idea of the magnitude of the work:

Name.	Date of Construction.	Total Length. Miles.	Length on Arches.	Remarks.
Appia	312 B. C.	11	Very little.	
Anio Vetus	272–264 B. C.	43	Very little.	
Marcia	145 B. C.	61	12 miles.	
Herculea Branch		3		
Tepula	126 B. C.	13	Very little.	
Julia	34 B. C.	15	6 miles.	
Virgo	21 B. C.	14	Very little.	
Alsientina	10 A. D.	22	Very little.	
Augusta	10 A. D.	6	Very little.	
Claudia	50 A. D.	46	10 miles.	
Anio Novus	52 A. D.	58	9 miles.	
Neronian Branch	97 A. D.	2	2 miles.	
Traiana	109 A. D.	42	Very little.	
Hadriana	117 A. D.	15	7 miles.	Restored 1585–1590.
Sabina Augusta	130 A. D.	15	Very little.	
Aurelia	162 A. D.	16	Probably 7 miles.	Elevated reservoir.
Severiana	200 A. D.	10	Not known.	
Antoniniana Branch	215 A. D.	3	3 miles.	
Alexandrina	226 A. D.	15	7 miles.	On Arches of Hadrian.
Totals		410	63 miles.	

Fig. 1.—Modern Roman Paving and Curb at Ponte St. Angelo.

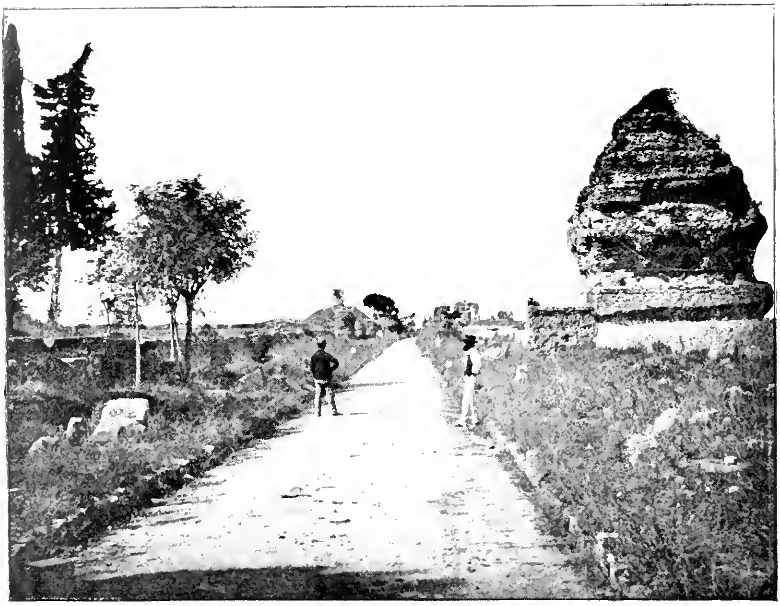


FIG. 2.—THE APPIAN WAY NEAR MOUNDS OF THE HORATII AND CURATII. ORIGINAL CURB VISIBLE; PAVING COVERED WITH BROKEN STONE.

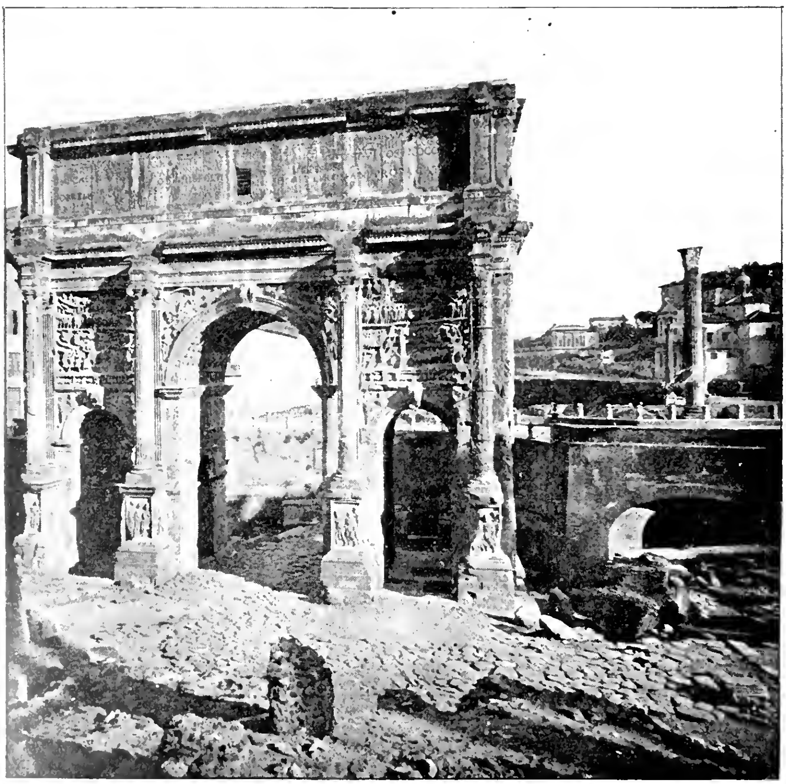


FIG. 3—THE VIA SACRA IN THE ROMAN FORUM, SHOWING PAVING SIMILAR TO THAT OF THE APPIAN WAY.

[Journal of the Association of Engineering Societies, Vol. XVII, No. 6, December, 1896.]

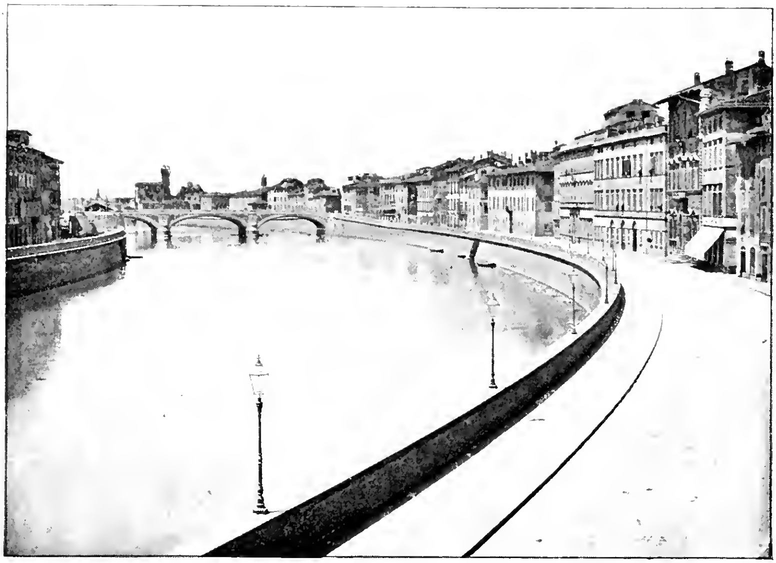


Fig. 4.—Confinement of the Arno at Pisa.

Fig. 5.—Cloaca Maxima in Roman Forum.

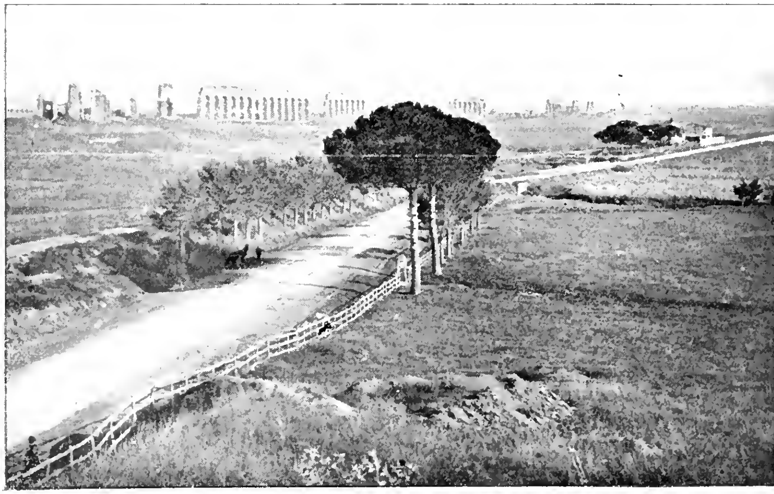


FIG. 6.—VIEW OF THE CAMPAGNA NEAR ROME, SHOWING CLAUDIAN AND OTHER AQUEDUCTS AND THE NEW APPIAN WAY.

FIG. 7.—AQUEDUCT OF CLAUDIA.

The city, although upon seven hills, lies in the valley some seven miles from the foot of a range of hills, and, to reach its higher parts, it was necessary to begin to elevate the conduit by a series of arches at the foot of the hills, and continue them to the reservoir within the city; some parts were double and as much as 109 feet in height. The greater part of each, however, was less than 50 feet high, and composed of a series of single arches. In some cases, there were two conduits upon the same arch, one above the other. The supply from the Marcian Springs, by the Aqua Marcia, was one of the largest, and the favorite with the people because of its coolness and salubrity. It was brought in by seven conduits, supported by two rows of arches, parallel to each other, and about fifty feet apart. A part of this magnificent work still remains, but most of it was destroyed by Pope Sextus V, and the material used in the restoration of the aqueduct of Hadrian in 1585–90.

Some of the aqueducts were entirely under ground, and the major part of all of them were. Only in two or three instances does any part appear above ground until within seven miles of the city. All of those whose source is twenty or more miles distant, make long detours to avoid streams and valleys For instance, the Marcian Springs are but thirty-six miles from Rome, yet sixty-one miles of aqueduct were built to conduct them thither.

Excepting the Anio Vetus and the Anio Novus, all the sources of supply were from springs or lakes, and the water clear and pure. The two named were taken from the river Anio, and, although settling and filtering basins were used, the water was at times turbid and unsatisfactory. In connection with this system were three large impounding reservoirs, created by dams built across the cañon of the Anio in the Symbraine mountains. The Anio Novus was an abundant supply, and, being the highest, it was sometimes used to reinforce the others, much against the will of the people, for at times it discolored any pure supply with which it was mixed. Most of the aqueducts were interchangeable at some point, and water could be turned out of one or more for repairs, without affecting the supply. The honor of beginning this system of water supply belongs to the censor Appius Claudius, better known as having built the road which bears his name. He constructed, B C. 312, the first aqueduct, which is almost entirely under ground, and which conveyed the waters from two springs to Rome, a distance of about eleven miles. Several of the older aqueducts were destroyed, and much of the material, used in their construction, was used again in later work of a similar character. Many of the most ancient were destroyed by the wars which finally caused the destruction of the Roman Empire, but the supply did not entirely cease until the fourteenth century.

In 1585–90 Pope Sextus V restored the aqueduct of Hadrian, and used therein, as stated, much of the material of the ancient Marcian and Claudian aqueducts. It is on arches for about six miles, and enters the city at the Porta Maggiore. It supplies many fountains of the present day.

Four of the ancient sources now supply the modern city, most of the water being brought in by iron pipes, only the upper or distant parts of the ancient conduit being utilized.

The conduits are from four to six feet high and always covered. When underground, they were lined with brick or stone. When the nature of the material required it they were plastered with cement which became very hard. At about every mile a bend was introduced, in order to break the force of the water and decrease its velocity, and at about every 240 feet, holes were left to admit air and to relieve the pressure should the conduits become too full. The Roman engineers had probably learned, by experience, that water would not flow freely in a closed conduit, not under pressure, unless air were introduced at frequent intervals, and therefore made openings near together for that purpose. It is by means of these respirators that the underground channels can be so readily traced.

It is to be inferred that the fall was ample, and greater than necessary, else they would not have introduced bends to check the velocity of the water.

The arches now standing are of stone or of brick, mostly of stone.

The generally prevalent idea that the Romans did not know that water would rise to the level of its source, is without doubt erroneous. Lead pipes, 3 inches in diameter, which had done service as water pipes in the palace of the Cæsars, are shown to visitors, and there is ample evidence that there was a distribution system of small pipes all over the ancient city. That they fully understood the natural laws which govern the flow of water is also unquestioned. They followed the contour of the country with their aqueducts, and doubtless built them, from controlling point to controlling point, upon a uniform grade, making tunnels when necessary, but, in the main, keeping the water line a short distance beneath the surface. This was the cheapest and most practicable method of construction with the materials available. When it became absolutely necessary to cross a valley, they raised the conduit above the surface of the ground upon arches of masonry, not because they did not know that water would rise again, but because they did not have, in sufficient abundance, material to construct a conduit that would carry a large quantity of water under pressure.

The longest tunnel in the vicinity of Rome was finished July 3, A. D. 88, and is under Monte Affliano, between Tivoli and S. Gericomio ;

it was 7 feet high, 3 feet wide and nearly three miles long. To supply the workmen with air is mentioned as one of the greatest difficulties encountered, but how this was accomplished is not stated. Lanciani records the discovery, in 1866, of a report upon some hydraulic work carried on in one of the African provinces, which throws some light upon the methods practiced by the engineers of those times. This report was engraved upon a marble altar, under the date A.D. 152, and reads as follows :

"Varius Clemens greets Valerius Etruscus, and begs him, in his own name, and in the name of the township of Saldæ, to dispatch at once the hydraulic engineer of the III legion, Nonius Datus, with orders that he finish the work, which he seems to have forgotten."

* * * *

Nonius Datus reported to the magistrates of Saldæ as follows:

"After leaving my quarters, I met with brigands on my way, who robbed me even of my clothes, and wounded me severely. I succeeded, after the encounter, in reaching Saldæ, where I was met by the governor, who, after allowing me some rest, took me to the tunnel. There I found every one sad and despondent. They had given up all hopes that the opposite sections of the tunnel would meet, because each section had already been excavated beyond the middle of the mountain, and the junction had not yet been effected. As always happens in this case, the fault was attributed to the engineer, as though he had not taken all precautions to insure the success of the work. What could I have done better? I began by surveying and taking the levels of the mountain; I marked most carefully the axis of the tunnel across the ridge; I drew plans and sections of the whole work, which plans I handed over to Petronius Celer, then governor of Mauritania, and in order to take extra precautions, I summoned the contractor and his workmen, and began the excavation in their presence, with the help of two gangs of experienced veterans.

* * * *

"What more could I have done? Well, during the four years I was absent at Lambæse, expecting every day to hear the good tidings of the arrival of the waters at Saldæ, the contractor and his assistant had committed blunder upon blunder. In each section of the tunnel they had diverged from the straight line, each toward his right, and, had I waited a little longer before coming, Saldæ would have possessed two tunnels instead of one."

The inscription further states that the connection was finally made by a transverse channel, and the arrival of the water celebrated by extraordinary rejoicings in the presence of the governor and the engineer.

To the mild, dry climate of Italy, more than to anything else, these

works owe their present state of preservation. In a more humid or colder climate, they would doubtless have been reduced to an unrecognizable mass. A comparison of the English with the Italian climate, in its effects upon the works of man, is aptly drawn by Hawthorne in the following lines from the "Marble Faun":

"The Italian climate, moreover, robs age of its reverence, and makes it look younger than it is. Not the Coliseum, nor the tombs of the Appian Way, nor the oldest pillar in the Forum, nor any other Roman ruin, be it as dilapidated as it may, ever gives the impression of venerable antiquity which we gather, along with the ivy, from the gray walls of an English abbey or castle, and yet every brick or stone, which we pick up among the former, had fallen, ages before the foundation of the latter was begun. This is owing to the kindliness with which nature takes an English ruin to her heart, covering it with ivy as tenderly as Robin Redbreast covered the dead babes with forest leaves. She strives to make it a part of herself, gradually obliterating the handiwork of man, and supplanting it with her own mosses and trailing verdure, till she has won the whole structure back. But, in Italy, whenever man has once hewn a stone, nature forthwith relinquishes her right to it, and never lays her finger on it again. Age after age finds it bare and naked, in the barren sunshine, and leaves it so."

ASSOCIATION
OF
ENGINEERING SOCIETIES.

VOL. XVII. | JULY, 1896. | No. 1.

PROCEEDINGS.

Boston Society of Civil Engineers.

JUNE 17, 1896.—A regular meeting of the Society was held in Chipman Hall, Tremont Temple, Boston, at 8.15 o'clock, P.M. President George F. Swain in the chair. Sixty-five members and visitors present.

The record of the last meeting was read and approved.

Messrs. Thomas T. Allard, Wilfred A. Clapp, Rudolph Hering and Louis B. Vaughan were elected members of the Society.

The President announced the death of James H. Stanwood, a member of the Society, which occurred May 24, 1896. On motion, the President was requested to appoint a committee to prepare a memoir and the following were named as members of that committee: Arthur G. Robbins and Henry P. Bryant.

On motion, the sum of $60 was appropriated for binding.

On motion of Mr. Whitney, the thanks of the Society were voted to the Metropolitan Water Board for courtesies shown this afternoon on the occasion of the visit to Dam 5, at Southborough.

The literary exercises of the evening consisted of a very interesting paper by President Swain on the "History of Stone Bridges." The paper was profusely illustrated by lantern slides and traced the development of stone arch bridges from the earliest times to the present day.

Adjourned.

S. E. TINKHAM, *Secretary.*

Association of Engineers of Virginia.—Summer Meeting.

THE Association of Engineers of Virginia held its Summer Meeting at Maple Shade Inn, Pulaski, Va., June 26, 27, 1896, and the meeting was pronounced by those present the most successful and enjoyable in the history of the Association. This verdict was chiefly due to the generosity of the management of the Norfolk & Western Railroad, who on the 27th placed a special train at our disposal to visit the zinc, lead, and iron mines and reduction works in the celebrated Cripple Creek re-

gion. The enjoyment was enhanced by the presence of several ladies who accompanied their husbands or relatives to the meeting, and the success of this innovation will, we hope, make the presence of ladies one of the features of subsequent Summer Meetings.

The papers read at the meeting were timely and were listened to with great interest. The one by Mr. G. R. Henderson, on "Locomotive Counterbalancing," caused the asking of many questions, and much interest was shown in the new steel piston head recently introduced on the Norfolk & Western, and in other devices introduced with a view to lessening the weight of the reciprocating parts. The paper by Mr. W. H. Adams, of Mineral City, on "The Gold Belt of Virginia," was on a subject about which most of us knew but little, and we felt greatly indebted to the author for enlightenment. When it came to looking at the nuggets and ore specimens we all caught the gold fever and were thankful that we were all goldbugs. The unanimous opinion seemed to be that the paper was a valuable one and should be published, but the author thought the time inopportune and made the condition before reading it that no part of it should be published at present.

The paper on "Good Roads," by Mr. J. R Schick, caused a discussion of the recent movement for good roads, and of the bill which was before the last legislature to enact a road law for the State. The bill was spoken of approvingly, and it was understood that we would help to secure its enactment by the next legislature.

The excursion on the next day was arranged in advance by Messrs. Coe and Churchill, and was carried out under the personal supervision of Mr. J. G. Osborne, Division Superintendent of the Norfolk & Western Railroad.

Captain J. C. Raper, Agent of Wythe Lead and Zinc Mine Co., was with the party during the whole day, and having been engaged in mining in that region for nearly forty years, could speak with authority on all matters pertaining to the region. At his works we saw the washing, jigging, and reduction of zinc and lead. Mr. G. M. Holstein, Vice-President and Manager of the Bertha Zinc and Mineral Co., was with us a part of the time, and placed every facility at our disposal, and Mr. McKee, Superintendent of Mines at Bertha, personally conducted the party at that place, showing the methods of working the zinc mines.

At Ivanhoe, Mr. George M. Seeley, General Manager New River Mineral Co., personally conducted the excursion through the iron mines, furnace, etc., belonging to his Company. At each place visited the local management did everything possible for our profitable entertainment, and when added to that we had the beautiful scenery of the New River valley, the presence of the ladies, and finally the excellent lunch furnished us by the Inn, we had a day long to be remembered by those fortunate enough to be able to attend the Summer Meeting of 1896.

ABSTRACT FROM THE MINUTES.

MAPLE SHADE INN, PULASKI, VA., June 26, 1896.—The meeting was called to order at 9 P.M. by the President, Prof. D. C. Humphreys. Fourteen members were present and a number of invited guests.

The following were elected members:

Robert E. Hutton, Lexington, Va.
F. H. Anschutz, Staunton, Va.
William Sleeper Aldrich, Morgantown, W. Va.
Theodore Low, Lynchburg, Va.
Ritchie Graham Kenly, Radford, Va.
M. J. Caples, of Bluefield, W. Va., was reinstated.

Mr. J. A. Pilcher, Secretary of the Association, stated in regard to the letter ballot sent out in order to ascertain the opinion of members on the bills pending in Congress for the establishing of the metric system, for the establishment of engineering experiment stations, and for the increase in the efficiency and personnel of the Navy; that while, with two or three exceptions to each bill, the replies favored the passage of the bill, they came in too late to be used at the recent session of Congress, but the result could be used in case the bills come up before another session of Congress.

A paper was read by Mr. G. R. Henderson on "Locomotive Counterbalancing," which was discussed and referred to the Committee on Publication.

Mr. W. H. Adams read a paper on "The Gold Belt of Virginia," which brought out many questions which the author answered in a most satisfactory way. At the request of the author the paper was not referred to the Committee on Publication.

Mr. M. E. Yeatman read a paper by Mr. James R. Schick on "Roads," which was discussed and referred to the Publication Committee. Adjourned.

On board excursion train June 27, 1896, before arriving at Pulaski on the return trip, a call meeting was held, presided over by the President.

The Association, by unanimous vote, thanked the Norfolk & Western R. R., The Bertha Zinc and Mineral Co., The Wythe Lead and Zinc Mine Co., The New River Mineral Co., and Mr. W. H. Hayes, manager of Maple Shade Inn, for courtesies extended to the Association.

Mr. J. G. Osborne, Division Superintendent Norfolk & Western R. R., was given a vote of thanks and reinstated to membership in the Association.

A vote of thanks was then given to the ladies of the party, and the meeting adjourned.

J. A. PILCHER, *Secretary.*

The Civil Engineers' Club of Cleveland.

THE July meeting of the Civil Engineers' Club of Cleveland, O., Tuesday evening, July 14, 1896, at the rooms of the School Council, President Howe in the chair. Present 82 members and visitors.

The minutes of the June meeting were read and approved. The Executive Board reported the resignation of Mr. C. W. Foote, and the applications of Messrs. John McGeorge and Carl C. Thomas.

Messrs. Aug. A. Honsberg and C. O. Palmer were appointed tellers to canvass the ballots for the election of Mr. Virgil E. Marani. Upon motion the question of the participation of the Club in the coming Centennial Celebration was referred to the Executive Board. It was voted to have a picnic, and also to have no August meeting. The paper of the evening, by Mr. H. F. J. Porter, of Chicago, was listened to with great interest. It was beautifully illustrated by lantern slides of photos and drawings. It gave an exhaustive description of the Bethlehem Iron Works at South Bethlehem, Pa., and their processes in the production of large forgings. The exhibition of photographic plates concluded with that of Mr. John Fritz, the founder of this great enterprise.

The speaker was followed by Messrs. Oldham and Newman, Dr. Langley, and others in interesting remarks, and Mr. J. F. Holloway appropriately finished the topic with a glowing tribute to the worth and ability of Mr. Fritz.

On motion of Mr. Mordecai, seconded by Mr. Cowles, an enthusiastic vote of thanks was tendered to Mr. Porter for his presentation of this paper.

President Howe announced the election of Mr. Marani, and named the Picnic Committee as follows: James Ritchie, W. O. Brown, A. L. Hyde, Hosea Paul and C. L. Saunders.

After the meeting a light lunch was served.

F. A. Coburn, *Secretary*.

Association of Engineering Societies.

Vol. XVII. **AUGUST, 1896.** No. 2.

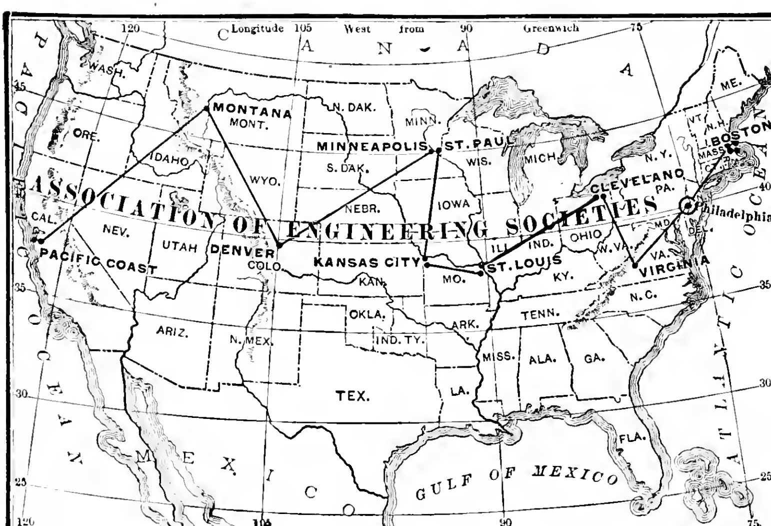
PROCEEDINGS.

The Technical Society of the Pacific Coast.

Regular Meeting, August 7th, 1896.—Called to order at 8.30 p.m., by Vice-President Curtis. The minutes of the last regular meeting were read and approved.

Mr. Luther Wagoner read a paper entitled: "The Law of Equal Settling Particles," which was discussed.

Otto von Geldern, *Secretary*, per F. A. V.



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Association of Engineering Societies.

Vol. XVII. **SEPTEMBER, 1896.** No. 3.

PROCEEDINGS.

Technical Society of the Pacific Coast.

Regular Meeting, Friday, September 4, 1896, held, according to previous arrangements, at the San Francisco Gas Works, at North Beach, through the courtesy of Mr. Edward C. Jones, who had invited the members and their ladies to an informal meeting of the Society.

President Dickie called the meeting to order.

Mr. Jones entertained and instructed the guests by reading a paper entitled "The Story of the X-Ray," and gave an interesting exhibition of an apparatus for creating the Roentgen Ray. A shadowgraph was taken in connection with the subject of the broken arm of a young lad, which was developed for inspection.

In addition to the reading of this paper, the members were conducted to the laboratory of the Gas Works, and were there shown the process of forming acetylene gas from calcium carbide, and the manner of using it for illuminating purposes.

An inspection of the gas plant closed the instructive entertainment of the evening, after which the meeting adjourned.

Otto von Geldern, *Secretary*.

Civil Engineers' Club of Cleveland.

Meeting of the Civil Engineers' Club of Cleveland, Tuesday evening, September 8, 1896, at the rooms of the Club, Case Library Building. Present, 33 members and visitors. Vice-President Ritchie in the chair. Minutes of the July meeting read and approved.

Messrs. A. Lincoln Hyde and Charles F. Lewis were appointed tellers to canvass the ballots for admission of John McGeorge and Carl E. Thomas to active membership.

Upon motion, committees were appointed by the chairman, as follows: Upon the death of Mr. Clarence O. Arey—Messrs. Coburn, Richardson and Hopkinson; upon the death of Mr. J. F. Holloway—Messrs. Swasey, Mordecai, Gobeille, Wellman, Strong and Paul.

Mr. Ritchie reported for the Picnic Committee, that the outing was a complete

success, the members having had a thoroughly enjoyable time; and that the committee had on hand twenty-five cents, after paying all expenses.

Mr. Swasey was then called to the chair, and the talk of the evening, upon "Some Examples in Recent Roof Construction," was given by Mr. Ritchie. The subject was thoroughly discussed by Messrs. Porter, Searles, Richardson, Hyde, Brown and others.

Messrs. McGeorge and Thomas were announced unanimously elected. The meeting then adjourned and the members proceeded to the restaurant.

F. A. COBURN, *Secretary:*

Engineers' Club of St. Louis.

439TH MEETING, SEPTEMBER 16, 1896.—The Club met at 8.35 P.M., at 1600 Lucas Place. President Ockerson in the chair and fourteen members present. The minutes of the 438th meeting were read and approved.

The Executive Committee reported the doings of its 217th, 218th, 219th, and 220th meetings. The Committee reported the establishment of a trust fund for the entertainment of visiting engineers, and referred to the Club the question of the best method of administering the trust. On motion, ordered that the fund be left in the hands of the Executive Committee, they to formulate a set of rules covering the matter, and to submit them to the Club for approval.

The Secretary was, on motion, directed to transmit to the local members of the American Society of Mechanical Engineers the thanks of the Engineers' Club of St. Louis for placing this trust in our hands, and for the contribution of the library fund of the Club.

The paper of W. J. Sherman, on the Galveston Harbor Works, was then read by Mr. B. L. Crosby, the author being absent. The paper gave a description of what is one of the most extensive improvements ever undertaken by the United States Government. The entrance to the harbor was impeded by a depth of only 12 feet on the outer bar, and 13 feet on the inner. The first improvements attempted were by dredging, without favorable results. The gabionade system was then undertaken, at great expense. No improvement resulted. The third project consisted of jetties of brush and stone. This bid fair to succeed, when it was found that the brush work was being destroyed by the sea worm known as the Teredo Navalis. The present scheme of two practically parallel solid rock jetties was then adopted, and is now in progress of construction. It has already deepened the outer bar to 20 feet, and it is believed that in good time it will reach the desired depth of 30 feet, with the aid of dredging.

The author gave the cost of the work, the rate of progress, and other interesting details.

Messrs. Crosby, Moore, Russell, and Barth participated in the discussion. Adjourned.

WILLIAM H. BRYAN, *Secretary.*

Boston Society of Civil Engineers.

SEPTEMBER 16, 1896.—A regular meeting of the Society was held in Chipman Hall, Tremont Temple, Boston, at 7.55 P.M. President George F. Swain in the chair; forty-two members and visitors present.

The record of the last meeting was read and approved.

Messrs. Frank H. Morris, Frank A. Peirce and Joseph H. Kimball were elected members of the Society.

The Secretary read a communication from the chairman of the Committee on Weights and Measures in relation to obtaining an expression of opinion of the members of the Society for or against the bill before Congress concerning the metric system. The communication stated that if the Society is desirous of obtaining such an expression, it will be necessary to make an appropriation of about $15 for printing and postage for the same. After a short discussion by Messrs. Brooks and Howland, a motion to appropriate the money asked for not having been seconded, the matter was allowed to drop without action.

Mr. George W. Blodgett then read the paper of the evening, entitled "Recent Practice in Railroad Signalling."

The paper was discussed by Messrs. Allen, Turner and Sampson.

On motion of Mr. Dorr the thanks of the Society were voted to Mr. C. D. Ingersoll, Jr., Resident Engineer, N. Y., N. H. & H. R. R., for courtesies shown this afternoon to members attending the excursion to inspect the work of raising the tracks of the Providence Division of that road.

Adjourned. S. E. TINKHAM, *Secretary*.

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ASSOCIATION

OF

ENGINEERING SOCIETIES.

VOL. XVII. OCTOBER, 1896. No. 4.

PROCEEDINGS.

Technical Society of the Pacific Coast.

REGULAR MEETING, OCTOBER 2, 1896.—This meeting was held in the great mercantile establishment, "The Emporium," on Market Street, in San Francisco, by invitation extended through the courtesy of the Management and the President, Mr. A. Feist.

The meeting was called to order by Mr. Dickie, who spoke of the engines and the special methods of condensation adopted.

Mr. Riflley explained the electric-lighting plant and installation, and other speakers followed in describing the different mechanical features of the establishment.

Mr. Feist addressed the Society on behalf of the Management.

An inspection was then made of the building, the pneumatic cashiering service, the elevators, the engines, the dynamos, the accountants' rooms and adding-machines, the restaurant, the kitchen, etc., etc., after which the meeting adjourned.

On motion of Mr. Grunsky, a vote of thanks was accorded Mr. Feist and the Emporium Company for the very interesting and instructive evening.

Attest, OTTO VON GELDERN, *Secretary.*

Civil Engineers' Society of St. Paul.

ST. PAUL, MINN., OCTOBER 5, 1896.—A regular meeting of the Civil Engineers' Society of St. Paul was held at 8.30 P.M.

Present, eleven members and one visitor. President Stevens in the chair.

The Secretary was instructed to accept, with thanks, the invitation of the echnical Club of Chicago to use club rooms.

A discussion of continuous rails on concrete foundation, in connection with asphalt pavements, was opened by Mr. Wilson and continued by Mr. Curtin, both well prepared to present results of practice and observation.

Adjourned at 10.30 P.M. C. L. ANNAN, *Secretary.*

Engineers' Club of St. Louis.

440TH MEETING, October 7, 1896.—The Club was called to order at 1600 Lucas Place, at 8.25 P.M., by Vice-President Flad. Seventeen members and one visitor present.

The minutes of the 439th meeting were read and approved. The executive committee reported the doings of its 221st meeting and submitted the following:

Rules and regulations governing the care, maintenance and disbursement of the engineers' entertainment fund:

The nucleus of this fund was derived from the local committee of the American Society of Mechanical Engineers, and a contribution from the Engineers' Club of St. Louis.

1. The fund shall be known as the Engineers' Entertainment Fund.

2. The Engineers' Entertainment Fund shall be devoted solely to the entertainment of distinguished engineers visiting our city, whether in conventions, small parties, or singly.

3. The fund shall be maintained as follows:

A. By interest on deposits.

B. By voluntary subscriptions.

C. By contributions from the treasury of the Engineers' Club of St. Louis, whenever in the judgment of the Executive Committee such contributions may be necessary and expedient—provided, however, that such contributions in any one year shall not exceed an amount equal to fifty cents for each resident member.

D. By special assessments, as provided in Section 2 of the By-laws.

4. The Executive Committee of the Engineers' Club of St. Louis shall have charge of the care, maintenance and disbursement of the Engineers' Entertainment Fund, subject to instructions from the Club when such action may be deemed necessary. Disbursements exeeeding $100 must first have the approval of the Club.

5. The affirmative vote of three members of the Executive Committee shall be required before any entertainment is undertaken. In emergencies, however, when a meeting of the Committee is impracticable—the president of the Club, or in his absence the vice-president, may anthorize such entertainment.

6. Any member of the Club may recommend the entertainment of visiting engineers to the Executive Committee, accompanying such recommendation with sufficient evidence of the propriety of such action.

On motion the above rules were approved.

The Secretary read a letter from the Technical Club of Chicago, inviting the members of this Club to use their Club rooms when in Chicago during 1896. On motion, ordered that the invitation be entered on the Club's records, that it be accepted, and that the Secretary make due acknowledgment.

Applications for membership were announced from Sidney W. Fornham Mechanical Engineer Missouri Pacific Coal Companies, and Charles F. Womeldorf, Draughtsman Water Works Extension.

Mr. Alfred Siebert then read the paper of the evening, on "Refrigeration," as applied to dwellings, hotels, hospitals, business houses and public institutions. He explained the different methods of refrigeration which have heretofore been used, and the advantages and disadvantages of each, calling particular attention to the merits of modern refrigerating machines. The different uses to which such machines may be put are: the cooling of rooms, ice making, freezing of carafes,

making ice cream and cooling air in living rooms. The cooling may be done either by the direct or indirect system, each having its advantages under certain conditions. The cooling of rooms may readily be combined with the indirect heating system.

Discussions followed by Messrs. Kinealy, Barth, Johnson, Flad and Crosby.

Mr. Carl Barth gave the Club an interesting discussion of a geometrical method of determining the best points of cut-off and compression, which subject was also discussed by Messrs. Kinealy and Flad. Adjourned.

WILLIAM H. BRYAN, *Secretary*.

441ST MEETING, OCTOBER 21, 1896.—The Club met at 1600 Lucas Place, at 8.20 P.M., Vice-President Flad in the chair. Twenty-three members and four visitors present.

The minutes of the 440th meeting were read and approved. There being no other business, Mr. William H. Bryan then read a paper on "Boiler Efficiency, Capacity and Smokelessness with Low Grade Fuel." The discussion now going on among the mechanical engineers of this country regarding the best method of expressing the economic performance of boilers was explained, and the revision of the generally accepted code for making boiler trials shown to be necessary. The author strongly advocated the statement of boiler efficiency in the percentage realized of the calorific value of the fuel, taking care that the coal used be carefully sampled, and its calorific power determined by the most accurate means possible. The writer presented a table giving the results of a large number of trials he had made to determine the efficiency and smokelessness of various types of boilers, with and without improved settings. The table gave the maximum, minimum and average results secured. The paper was accompanied also by a table of fuel analyses and calorific determinations covering all the common Southern Illinois coals coming to this market.

Discussion followed, participated in by Messrs. Russell, Kinealy, Flad. Moore, Wheeler, Leighton, Ashburner, Harrington, and Wm. T. Bonner, of Cincinnati.

Adjourned. WILLIAM H. BRYAN, *Secretary*.

The Civil Engineers' Club of Cleveland.

MEETING held Tuesday evening, October 13, 1896, at the rooms of the Club in the Case Library Building; Vice-President Ritchie in the chair. Present, fifty-one members and visitors.

The minutes of the September meeting were read and approved.

The Secretary reported for the Executive Board the resignation of Mr. E. W. S. Moore, and the applications for active membership, of Messrs. Alex. Raynal and Wm. C. Thayer.

Committees presented resolutions upon the death of Mr. J. F. Holloway and of Dr. C. O. Arey, as below. They were unanimously adopted by a rising vote.

Remarks appropriate to the occasion were offered by Messrs. Warner, Gobeille, Kimball and Searles, and letters were read from Mrs. Holloway and Mr. F. H. Richards.

A letter from the Technical Club of Chicago, extending an invitation to members of this Club to visit their club-rooms whenever in Chicago, was read.

Mr. Varney then presented the paper of the evening, entitled "Solar Work in Land Surveying." Mr. Varney's clear description of the principles governing solar work, and of a new device for use in that method of land surveying, was very fine and well appreciated by the members of the Club. In the discussion which followed, Messrs. Culley and Baker took an interesting part.

After the meeting a light lunch was served.

F. A. Coburn, *Secretary.*

Cleveland, O., October, 1896.—A semi-monthly meeting of the Club was held on Tuesday evening, October 27, 1896, at the rooms in the Case Library Building. Present, fifty-seven members and visitors.

Mr. Cecil L. Saunders read a paper entitled "Gas Producers and the Mechanical Handling of Fuel." The subject was presented under the following heads: A Discussion of Various Types; The Necessity for Attention to Detail of Construction; The Relation of Character of Coal to Type to be Used; A Possible Field for Future Economy; Coal Handling from Hoppers; Unloading Coal by Mechanical Devices.

Messrs. Sperry, Mordecai, Barber and others took part in an interesting discussion.

After the meeting a light lunch was served.

F. A. Coburn, *Secretary.*

CLARENCE O. AREY, C.E., M.D.—A MEMOIR.

In Dr. Clarence O. Arey, the Civil Engineers' Club of Cleveland lost one of its brightest and most honored members.

We recall that he came to Cleveland a graduate of the School of Engineering of the State University of Michigan, having been engaged, immediately after leaving college, with prominent architects in Buffalo and Chicago.

We remember the enthusiasm with which he entered the architectural field of Cleveland, and his aim to combine the training of an engineer with the experience of an architect. For ten years he labored faithfully and well, winning laurels on every hand for his sober, consistent, scholarly work and his honorable record. Having more of the training and spirit of a civil engineer than was generally common with architects, he naturally sympathized strongly with our Civil Engineers' Club and its work, and was more than ordinarily interested in the broadening of the two professions in their mutual relations. His able and interesting papers, delivered before us from time to time, abundantly illustrated his spirit, his ambitions and his mental strength. And when, through personal losses in his family, his mind turned toward the great field of bacteriological work, and he elected to carry his experience, his studious habits, and his conscientious zeal into this new field of research, we felt that truly no one of our members was better fitted to enter it.

His success in his new work, which was to be the chosen work of his middle and later life, was soon manifested. We recall the confidence which he won from the professors and physicians connected with the Western Reserve Medical College, where his active bacteriological work was conducted. Surely he would have reaped large honors had he been spared to prosecute this work. Those who listened to the masterly paper on "Water Supply and Sewerage as affected by the Lower Vegetable

Organisms," which was read at the June meeting of this year, will remember the ability shown, and the patient study exhibited.

He was about thirty-nine years old at his death, an age when life is seen with the cool, dispassionate vision of fully matured manhood, when the powers take on new vigor and strength.

Honorable and upright in the smallest, as well as in the largest matters entrusted to his care, he was one such as the world delights to honor.

To his widow and his two little children we extend our heartfelt sympathy and commiserations.

Therefore be it Resolved, that we hereby express our deep-felt regrets at Dr. Arey's death and that we forward a copy of the same to his bereaved family, and also spread upon the minutes of the Club a copy, that future members may know of our sincere regard for him.

F. A. COBURN,
JNO. N. RICHARDSON,
CHAS. W. HOPKINSON, } *Committee on Resolutions.*

JOSEPHUS FLAVIUS HOLLOWAY.—A MEMOIR.

MR. JOSEPHUS FLAVIUS HOLLOWAY was born in Uniontown, Stark County, Ohio, January 18, 1825, and he died at Cuyahoga Falls, Ohio, September 1, 1896.

It is impossible for the Civil Engineers' Club of Cleveland to express its sense of loss, in words that will appear other than trite and commonplace, at the death of Josephus Flavius Halloway, for his death is not only a great loss to this Club, but much more so to its individual members. He was our friend and our adviser; he knew our names, our work, our circumstances, and was ever ready with congratulations and praise for our individual successes, as well as with encouragement and sympathy when we were cast down. It is exceedingly difficult to come together as a Club, and express in words, that which is more plainly told by the moistened eye and saddened brow, for our memory pictures before us his ever gentle and genial personality whenever we hear the mention of his name.

We are proud to speak of his achievements, for he devoted his life to the field of engineering at a time when there were almost no technical schools and very few books of reference; when it was necessary to solve great problems by personal experiment, such as now can be put upon the board in a few minutes by the use of simple formulæ; at a time, too, when progress (which necessarily involves change) was forced upon this country because of the necessities of utilizing our great lakes and rivers as means of transportation; of building our railways, opening our mines, and meeting the demands of urban life. It certainly was not easy then for this simple country boy to achieve a reputation which is wider than the continent. He was one of the founders of this Club, for three successive terms its President and one of its honorary members; he was chosen President of the American Society of Mechanical Engineers, Vice President of the American Institute of Mining Engineers, and President of the Engineers' Club of New York. He held the position of President and Engineer of the Cuyahoga Steam Furnace Company of Cleveland, Vice-President and Consulting Engineer of the Worthington Hydraulic Works, and after that, until the time of his death, Consulting Engineer for the Snow Steam Pump Works. But we need not proclaim his standing as an engineer, so we pass his eminent professional career to note other characteristics and accomplishments just as prominent.

First was his high standing as a Christian gentleman. No question of morals or ethics but found Mr. Holloway on the right side, and all his life long its ardent champion. He was possessed of intense desire to promote the universal brotherhood of man, and was especially full of sympathy for the artisan; as is indicated by his address to the workmen of the Cuyahoga Steam Furnace Company after the sale of that plant, one of the most pathetic bits of literature ever written in that line.

In his domestic life he was perhaps seen at his best, and to his sorrowing widow and to his son and daughter, the sympathy of those who had the good fortune to share his hospitality, is instinctively tendered. Happily his son bids fair to emulate his father's example and standing.

Mr. Holloway was especially noted for his literary accomplishments. His contributions to the engineering literature of the day were of the highest order, and always interesting and instructive. Very early in life he conceived a warm admiration for Dickens' works, and he accumulated later a noteworthy library of volumes bearing upon this author and his works. It is doubtful whether any man in the United States had a better knowledge than he of the works of Dickens, of the characters he created, or of the motives and sympathies which inspired the author in formulating the plots of his books.

Socially, Mr. Holloway was one of the most lovable and enjoyable of men. His quiet and even disposition, his ready and clear wit—never sharpened by pointed or ill-natured remarks—left nothing but pleasant memories behind. His thorough appreciation of others, and his consideration for them, made him a prince of entertainers; and those who remember him as speaker or as toast-master at our banquets, know how much we owe to this gentle, quiet, and sympathetic character. To the younger and more retiring members of the profession, he was especially encouraging and helpful, being ever a welcome counselor among them, and so it was with all with whom he was associated.

Indeed, the following words spoken by him in memory of his beloved friend, Alexander Lyman Holley, are equally true of Josephus Flavius Holloway: "When his biography shall be truly written, it will be found, that while his accomplished work and deeds as an engineer will give him a place among the ablest in the profession he so well adorned, his highest and best monument will be found in the loving memory of him, that will ever linger in the hearts of his friends."

Ambrose Swasey,
Augustus Mordecai,
Joseph Leon Gobeille,
S. T. Wellman,
C. H. Strong,
Hosea Paul,

Committee on Resolutions.

Association of Engineering Societies.

Vol. XVII. NOVEMBER, 1896. No. 5.

PROCEEDINGS.

Civil Engineers' Society of St. Paul.

A regular meeting of the Civil Engineers' Society of St. Paul was held on November 2, 1896, at 8.45 P.M.

Present ten members and six visitors. President Stevens in the chair.

The discussion of the evening was led by Mr. H. H. Vaughan, M. E., of the Great Northern Railway Co., and was suggested by incidents of a recent visit to the shops of the company by fourteen members of the Society.

These shops are equipped with laboratories for mechanical and chemical tests and pneumatic appliances are in general use in the various departments.

The discussion was continued and somewhat broadened over the tables at Neuman's after 10 o'clock. C. L. Annan, *Secretary*.

Engineers' Club of St. Louis.

442d Meeting, November 4, 1896.—President Ockerson called the Club to order at 8.30 P.M., at 1600 Lucas Place. Twenty-six members and four visitors present.

Mr. Julius Baier was, on motion, elected Secretary *pro tem.* The minutes of the 441st meeting were read and approved. The doings of the 222d meeting of the Executive Committee were reported, recommending the applications for membership of Messrs. S. W. Farnham and Chas. F. Womeldorf. They were balloted for and elected. The receipt of the following publications for the library was announced: Annual Report of the Massachusetts State Board of Health, Appletons' Cyclopedia of Drawing and Design, presented by Mr. W. E. Worthen, and Seventh Annual Report of the Syracuse, N. Y., Water Board. The Secretary was directed to make due acknowledgment. The Secretary read a letter from the American Street Railway Association acknowledging courtesies extended by this Club during their recent convention.

Mr. M. L. Holman then presented informally the proposed specifications and form of contract prepared by the Board of Public Improvements for the lighting of

the streets, alleys and public places of the city of St. Louis for a term of twenty years, beginning in 1900. The most important features of the proposed contract were the exclusive use of 32 candle-power incandescent lights in place of the arcs of 2000 nominal candle-power, all wires to be underground.

St. Louis was the first large city to adopt electric lighting on a large scale, and has therefore had a very wide and valuable experience, arcs being used for the streets generally, and incandescents for the alleys, parks, and also for a number of suburban streets. Valuable practical experience had therefore been had in the use of both kinds of lights, and the adoption of the incandescent light to the exclusion of the arc is the result of a careful investigation into the illumination given by the two systems.

The duration of the contract was made twenty years in order that the city might secure reasonable bids.

Diccussion followed by Messrs. R. E. McMath and B. H. Colby, who, with Mr. Holman, formed the sub-committee of the Board which had this work in hand. They emphasized the fact that their conclusion was based upon actual observations made on the two systems of lighting in regular service in this city. The arc lights give a very unequal distribution, the illuminations being very intense at one point and there being but little light midway between. The incandescent lights, on the other hand, are placed much nearer together and afford a much more uniform light.

Further informal and general discussion followed, in which Messrs. Robert Moore, Eayrs, Crosby, Barth, Van Ornum, Ockerson, Pitzman, Wise and Philip Moore participated. Adjourned.

Julius Baier, *Secretary pro tem.*

443d Meeting, November 18, 1896.—The Club was called to order at 8.40 P.M. at 1600 Lucas Place. Vice-President Flad in the chair, twenty-two members and four visitors present. The minutes of the 442d meeting were read and approved. The Executive Committee reported the doings of its 223d meeting. An application for membership was announced from W. N. Graves, general superintendent Hydraulic Press Brick Company, endorsed by F. H. Pond and William H. Bryan.

The Club then proceeded to ballot for a Committee on Nomination of Officers for 1897, the Committee to report at the next meeting. The balloting resulting in the selection of S. E. Freeman, F. B. Maltby, J. A. Laird, Julius Baier and S. B. Russell.

Mr. Carl Barth then gave the Club an informal talk on the Emery Testing Machine, in the development of which he took a prominent part. This machine, which was the invention of Mr. A. H. Emery, C. E., is one of the most wonderful inventions of the age, embodying many new principles, and working absolutely without friction. It is capable of giving the most accurate results, whether the load be large or small. Mr. Barth exhibited a number of lantern slides, showing the general appearance of the machine, and its most important details. Brief discussion followed, participated in by Messrs. Freeman, Harrington, Baier and Russell.

Prof. J. B. Johnson showed the Club a new form of cement briquette, which he had designed with a view of securing more accurate results in cement testing. He

showed wherein the ordinary form of briquette was imperfect, and gave the theoretical considerations governing his design and the results it has given in practice. Adjourned.

WILLIAM H. BRYAN, *Secretary.*

Technical Society of the Pacific Coast.

REGULAR MEETING, NOVEMBER 6, 1896.—Called to order by President Dickie.

The minutes of the last regular meeting were read and approved.

The application for membership of Edward F. Haas, proposed by H. I. Randall, Frank Soulé and Hermann Kower, was referred to the Executive Committee for the usual action.

Professor Albert T. Smith spoke to the members on the subject of "Proper Shapes in Machine Design," illustrating his lecture by numerous diagrams on the blackboard. This interesting subject was discussed by President Dickie, A. d'Erlach, Mr. Buchanan and others.

Adjourned. OTTO VON GELDERN, *Secretary.*

The Civil Engineers' Club of Cleveland.

THE November Meeting of the Club was held in the rooms of the School Council, Public Library Building, Tuesday evening, November 10, 1896. Mr. W. H. Searles was chosen chairman. Present fifty-two members and visitors. The minutes of the two preceding meetings were read and approved. Messrs. S. J. Baker and August Honsburg were appointed tellers to canvass the ballots for admission to active membership of Alfred H. Raynal. Mr. Hyde reported, at the request of the Chairman, in regard to the progress of the proposed amalgamation of the technical societies of this city.

Joseph R. Oldham, N. A. and M. E., then read the paper of the evening, on "Structural Strength of Ships and Improved Arrangements for Repairing without Diminution of Strength."

Mr. Oldham's paper treated of matters under the following heads: Progression by Steps in Engineering; Increase in Steel Lake Tonnage; Bending Moment and Shearing Stress; Strength of Beams and Girders; Straining of Ships; Improved Hatches; Useful Weak Ships; Joggling and Lapping; Flush Bottoms; Heavy Ships; Light Ships; A Perfect Mechanical Structure.

Messrs. Newman, Searles and Head followed in an interesting discussion. Mr. Raynal was reported unanimously elected.

After the meeting a light lunch was served.

F. A. COBURN, *Secretary.*

Montana Society of Civil Engineers.

THE November meeting of the Montana Society of Civil Engineers was held Saturday evening, November 14th.

The applications for membership of William A. Clark, of Butte, and Frank

Leonard, of Libby, were read and the Secretary was directed to send out letter ballots to the members, to be canvassed at the next regular meeting.

Prof. Ryon's report on Senate bill No. 2301, which provides for the establishment of engineering experimental stations in each State by the general government, was approved by the society.

A letter from Prof. Ryon, in which he expressed a desire to withdraw from active membership owing to the fact that he had left the State, was read. He was placed upon the list of associate members.

Messrs. Carrol, Taylor and Bickel were appointed a committee to place in nomination a list of candidates for officers for the ensuing year. Messrs. Keerl, Blackford and Parker were named a committee to arrange for the annual meeting, to be held the second Saturday in January. The meeting will be held in Great Falls, and while there the members will visit the smelters, the dam, the giant spring and the Sand Coulee coal mines and other points of engineering interest.

F. W. Blackford, City Engineer of Butte, read a paper on "A Few Points of Interest Observed on a Short Trip Abroad. Pavements, Confined Rivers and Water Supply of Ancient Rome." His description of the Appian Way and the modern pavements of London and Paris left little doubt that American cities have still much to learn. Mr. Blackford also exhibited a fine collection of views of some of the various points of interest which he visited.

After the paper was discussed it was referred to the trustees, who will publish it in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

There were present at the meeting: F. W. Blackford and Eugene Carroll, of Butte; Maurice Parker, of Great Falls; and John Herran, A. E. Cumming, F. J. Smith and A. S. Hovey, of Helena. The visiting engineers were J. M. McGregor, of Rossland, B. C.; Mr. King, of Great Falls, and F. L. Sizer, of Helena.

F. J. SMITH, *Secretary.*

Association of Engineering Societies.

Vol. XVII. DECEMBER, 1896. No. 6.

PROCEEDINGS.

Boston Society of Civil Engineers.

October 21, 1896.—A regular meeting of the Society was held in Chipman Hall, Tremont Temple, Boston, at 7.50 p.m. President George F. Swain in the chair, 95 members and visitors present.

The record of the last meeting was read and approved.

Messrs. Rowland H. Barnes, Edward D. Bolton, Isaac W. Hastings, Alfred T. Palmer and Charles H. Peck were elected members of the Society.

The Secretary read a memoir of James H. Stanwood, a member of the Society, prepared by a committee of the Society, consisting of Messrs. A. G. Robbins and H. F. Bryant.

The President announced the death of Past President Albert F. Noyes, which occurred on October 12, 1896, and in accordance with the usual custom appointed as a committee to prepare a memorial, Messrs. G. A. Kimball and H. D. Woods.

Mr. Main, for the Committee on Weights and Measures, presented a report, giving the result of a canvass of the Society to obtain the consensus of opinion on the proposed action of Congress with relation to the use of the Metric System. Mr. Howland objected to such an announcement being made, for the reason that the Society at its last meeting had declined to appropriate money for the purpose of making this canvass. The President ruled that the Committee on Weights and Measures could submit such a report, and upon an appeal being taken from the ruling of the chair, his decision was sustained. Mr. Main then read the following report:

The Committee on Weights and Measures was requested to obtain a consensus of opinion on the proposed action of Congress with relation to the use of the Metric System.

At the last meeting of the Society the estimated cost of getting this consensus was stated to be about $15, but the Society did not see fit to make an appropriation for this purpose. Since the meeting, the necessary amount has been received by the Committee independent of the Society.

Postal cards reading as follows were sent to each member:

"I am——in favor of the passage by the present Congress of an Act requiring the metric weights and measures to be in use by the government departments generally by the beginning of the Twentieth century, January 1, 1901.

"I should——be willing to have people generally of their own acord adopt metric weights and measures for their ordinary business transactions, and especially for those in which I am myself concerned, at the same time at which the government departments as a whole actually do adopt them."

The total number of cards sent out was	404
The total number of cards returned was	229
Number in favor of both clauses of the card	193
Number against both clauses of the card	21
Number for first clause and against second	2
Number against first clause and for second	11
Members in favor of a decimal system	2

Respectfully submitted,

CHAS. T. MAIN,

For the Committee on Weights and Measures.

Mr. John L. Howard was introduced and read a paper entitled "A brief Account of Topographical Work on Mr. George W. Vanderbilt's North Carolina Property."

Mr. Henry F. Bryant followed with a paper entitled "Topographical Surveys of the Metropolitan Park Reservations of Massachusetts."

The papers were fully illustrated by maps showing the work covered.

A general discussion followed, in which Messrs. A. H. French, W. E. McClintock, E. P. Adams and others took part.

Adjourned. S. E. TINKHAM, *Secretary.*

NOVEMBER 18, 1896.—A regular meeting of the Society was held in Chipman Hall, Tremont Temple, at 7.45 P.M. President George F. Swain in the chair. Total number present 227. The members of the Society of Arts of the Massachusetts Institute of Technology were invited to join in this meeting and a number availed themselves of the invitation.

The record of the last meeting was read and approved.

Messrs. Alton D. Adams, Fred Lavis and Eugene E. Pettee were elected members of the Society.

The Secretary presented, for the Board of Government, the following rules with regard to the circulation of the books of the Library, which the Board recommended to be adopted in place of those now in force:

Books and periodicals may be used in the Reading-Room by members and friends, and by students recommended by the Boston Public Library.

Members may borrow books for home use, but no one shall have more than four books at any time, nor keep any book more than five weeks.

A member borrowing a book shall give a receipt therefore to a member of the Library Committee, to the Secretary, or to the regular attendant.

A fine of one cent per day per volume shall be charged for overtime, and must be paid before the delinquent can take any more books.

Current numbers or unbound files of periodicals shall not be taken from the room.

Books of unusual value are marked with a star (*), and must not be taken from the room, except by written permission from the Board of Government.

Any person mutilating or losing a book shall pay for the damage, or replace the book.

Any one who violates the above rules shall, upon written request from the Librarian to the Board of Government, be debarred from the privileges of the library for such time, not less than three months, as the Board of Government may determine.

On motion of Mr. French the recommendation of the Board was adopted.

On motion of Mr. Thompson the thanks of the Society were voted to the George F. Blake Manufacturing Co., for courtesies shown the members this afternoon on the occasion of the visit to the Company's works at East Cambridge.

Mr. E. L. Corthell was then introduced and delivered a lecture entitled "The Tampico Harbor Works, Mexico, with Some Remarks upon the Mouth of the Mississippi River."

The lecture was profusely illustrated with lantern slides and plans.

Adjourned. S. E. TINKHAM, *Secretary.*

DECEMBER 16, 1896.—A regular meeting of the Society was held in Chipman Hall, Tremont Temple, Boston, at 7.50 P.M. Vice-President Dexter Brackett in the chair. Sixty-two members and visitors present.

The record of the last meeting was read and approved.

Messrs. Samuel D. Dodge, Frank E. Fuller, Ralph E. Marston, Elmer W. Ross, and Henry A. Symonds were elected members of the Society.

The Secretary read a memoir of Forrest L. Libbey, a member of the Society, prepared by a committee appointed for that purpose.

Mr. F. Herbert Snow then read the paper of the evening on Sewer Assessments.

The paper was discussed by Messrs. Hazen, G. A. Kimball, C. R. Cutter, F. P. Stearns, Coffin, Hawes and others.

The Secretary also read in full, discussions prepared by Messrs. T. H. Barnes and George Bowers, and by titles a number of other contributions, which would be printed with the proceedings.

President Swain assumed the chair and on motion of Mr. Whitney, the thanks of the Society were voted to the managment of the New York, New Haven & Hartford Railroad for its generosity in placing a special car at the disposal of the Society for the proposed excursion to Providence.

Adjourned.

S. E. TINKHAM, *Secretary.*

James Hugh Stanwood.—A Memoir.

BY A. G. ROBBINS AND H. F. BRYANT, COMMITTEE OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Society, October 21, 1896.]

JAMES HUGH STANWOOD was born at Brunswick, Me., July 17, 1860. He began his professional life in 1879, when he entered the employ of Edward C. Jordan, Civil Engineer, of Portland, Me.

During the two following years he was engaged in general engineering-work in and near the city of Portland.

From 1881 to 1883 he served as leveler and transmit-man in the engineering department of the Maine Central Railroad.

In order to more thoroughly equip himself for his profession, he entered the Massachusetts Institute of Technology in 1883, and four years later graduated from its civil engineering department.

In 1887 he entered the office of the designing engineer of the Philadelphia

Bridge Works, at Pottstown, Pa., where he remained a year, when he resigned his position in order to return to the Institute of Technology as an assistant in civil engineering. Two years later he became an instructor, and for several years previous to his death, he was in charge of the drawing-room work in bridge and roof design. During this time he was also an instructor in mechanical drawing in the Boston evening schools.

Among his pupils he was considerate, uniformly courteous, and untiring in his efforts to make clear the principles underlying the subject, and to point out the application of those principles to the particular design in hand.

Among his friends and acquaintances he was always frank and manly, with an abundance of good humor, which, together with his high character and generous disposition, made him most esteemed among those who knew him best.

Of his contributions to engineering literature, perhaps the most widely known is his "column formulas" for yellow pine posts, printed in the *Railroad Gazette* in 1892 and 1894.

He was a member of this Society from September 17, 1890, till his death on May 24, 1896.

He was also elected an associate member of the American Society of Civil Engineers on October 3, 1894.

Forrest L. Libby.—A Memoir.

By Henry Manley, S. E. Tinkham and N. S. Brock, Committee of the Boston Society of Civil Engineers.

[Read December 16, 1896.]

Forrest Llewellyn Libby was born at Great Falls, N. H., August 19, 1864. He came to Boston in 1869, and was educated in the Boston Public Schools, graduating from the Roxbury High School in 1879. On November 1, 1881, he entered the office of the City Engineer of Boston, and remained in its employ until his death on July 21, 1894. For the first eight years of this time he was employed in the central office, principally upon the construction of bridges, in connection with structures of an allied character, such as wharves, sea-walls, etc.

During this time he had a part in the construction of the following structures, besides much other miscellaneous work: Warren and Meridian Street Bridges, Albany Street, Broadway and Boylston Street Bridges, over the Boston & Albany Railroad, Wharves at Long and Deer Island, and East Boston Ferries.

In December, 1889, an opportunity for promotion transferred him to the force employed upon Dam No. 6, of the Boston Water Works, and upon this work and upon surveys and studies for the further extension of the water works system he was employed until his death.

It early became evident that he was suffering from the incurable malady which finally caused his death. He continued unflinchingly at his post, however, until December 24, 1892, when by advise of his physician and friends he went to Southern California, in the hope of restoring his now much impaired health. This hope proved vain, for his return in May 1893 found him little improved.

With the courage and perseverance which characterized him to the last, he again attempted active work in July, 1893, and, although frequently compelled to give up for intervals of a few days, he continued the struggle till January 25, 1894, when he broke down completely; from this time he failed steadily until his death on July 21st.

Although ill for many months and at times suffering severely, he bore his part of the work faithfully and willingly, never asking for favor and never giving up till absolutely compelled to.

He joined the Society November 15, 1885. He was unmarried.

He leaves behind him many friends, who remember his prompt, quick ways and active habits, who admire the courage always shown by him and particularly in his long fight with a wasting disease, and who sympathize with his family in the pathetic ending of a life cut short before its time.

Engineers' Club of Minneapolis.

MINNEAPOLIS, MINN.—A meeting of the Engineers' Club of Minneapolis was held November 16, 1896, at 8.00 P.M., in the Council Chamber, City Hall. President F. W. Cappelen in the chair.

The committee appointed at the last meeting to solicit subscriptions to extinguish the indebtedness of the Club, reported verbally that they had accomplished the object of their appointment, and submitted a draft on New York for $77.28 as their written report.

Their report was accepted, and, on motion, the thanks of the Club were extended to them and to the several subscribers to the same, and the Secretary was directed to notify them of the Club's action.

Mr. F. W. Cappelen then read a paper on "Cost of Electric Lighting in the United States."

After informal discussion, a motion was passed, "That a committee, to further discuss this subject, and to make further deductions from the voluminous table submitted by Mr. Cappelen with his paper, to be presented to the Club and published in the JOURNAL, be appointed." On motion, adjourned.

ELBERT NEXSEN, *Secretary.*

MINNEAPOLIS, MINN.—A meeting of the Engineers' Club of Minneapolis was held at the office of the City Engineer, City Hall, Tuesday, December 29, 1896, at 8 P.M. President F. W. Cappelen in the chair.

Minutes of previous meetings were read and approved, after correcting those of the last meeting relative to report of Committee on Debt Extinguishment, as follows: The Committee, having failed to accomplish anything, the President took the matter in hand with the success indicated in the report.

There were read communications from Charles B. Billin, Secretary, extending to our members an invitation to use the rooms of the Technical Club, of Chicago, when in that city; an invitation from the Western Society of Engineers to our President and Secretary to attend their annual banquet, and a letter from John C. Trautwine, Jr., Secretary Association of Engineering Societies, enclosing sample letter-head and offering electrotype of map for our use.

The Secretary was directed to thank the Technical Club of Chicago, and to accept Mr. Trautwine's offer.

The draft of a bill, embodying proposed legislation on the subject of licensing "Measurers of Land," presented by Mr. William Danforth, of Redwing, was read, and referred to a committee, consisting of E. T. Abbott, Ellis R. Dutton and J. E. Egan, appointed, under a motion, "That a committee of three be appointed to act with committees from Civil Engineers' Society of St. Paul, the Surveyors' Society of

Minnesota and the University of Minnesota, to prepare a bill and endeavor to have it passed, as will correct the many faults of the present laws relative to measuring, or surveying of land."

Charles E. Pillsbury and C. H. Kendall were unanimously elected members of the Club.

Mr. George D. Shepardson, C.E., read a paper on "Some Principles of Artificial Lighting," which was discussed, and he was requested to furnish a copy for publication. On motion, adjourned.

ELBERT NEXSEN, *Secretary*.

Engineers' Club of St. Louis.

444TH MEETING, DECEMBER 2, 1896.—The annual meeting was held at 1600 Lucas Place. Vice-President Flad called the meeting to order at 8.10 P.M. Thirty members and twelve visitors present, three of the latter being ladies. The minutes of the 443d meeting were read and approved. The Executive Committee reported the doings of its 224th meeting approving the application for membership of W. N. Graves, general superintendent Hydraulic Press Brick Company. He was balloted for and elected. An application for membership was announced from C. E. Delafield, engineer of construction St. Louis Electric Light and Power Company, endorsed by B. H. Colby and A. H. Zeller.

The Secretary then read his annual report giving a summary of the Club's work for the year just past. On motion, this report was ordered received and filed. Thos. B. McMath, treasurer, then read the annual report of the Club's finances. On motion, ordered referred to the Executive Committee to be audited. The Committee on Improvement of Library, Julius Baier, chairman, then made a report which was on motion accepted and the committee discharged with thanks, its work having been completed.

Prof. J. B. Johnson made a report for the Board of Managers stating that only routine business had been transacted during the past year.

Vice-President Flad then submitted a report summarizing the work of the Executive Committee for the year, showing a gratifying improvement of the Club's finances. On motion received and filed.

Col. E. D. Meier, Chairman of the Committees on Monument to Capt. Eads and Standard Gauges for Thickness, stated that these committees had nothing special to report, and asked that they be continued.

The Secretary stated that he was in receipt of a letter from the Librarian stating that continued absence from the city had prevented his preparing a formal report.

The Committee on Smoke Prevention made no report.

S. Bent Russell read the report of the Nominating Committee as follows:

For President: Edw. Flad.

For Vice-President: William H. Bryan.

For Secretary: Richard McCulloch.

For Treasurer: Thos. B. McMath.

For Librarian: W. A. Layman.

For Directors: J. A. Ockerson and B. H. Colby.

For Board of Managers: J. B. Johnson and E. A. Hermann.

Other nominations being called for, Mr. Carl Gaylor was nominated for vice-president.

The Secretary called attention to a letter from Mr. W. A. Layman stating that it would be impossible for him to serve the Club further. On motion ordered that Mr. Layman's name be withdrawn from the ticket and that of Mr. Julius Baier substituted.

On motion of Mr. Crosby, it was ordered that the Club have its usual annual dinner and that the Executive Committee make the necessary arrangements.

Prof. J. B. Johnson then showed the Club a large number of lantern slides which had been prepared originally to accompany his paper recently read before the St. Louis Railway Club on "The Mechanical Properties of Wrought Iron and Steel, as Shown by Actual Tests," the views being shown this Club by special request. The Professor stated that the paper had already been published in full, including most of the views, and he would be glad to furnish copies to those interested. Adjourned.

WILLIAM H. BRYAN, *Secretary*.

445TH MEETING, DECEMBER 16, 1896.—The annual dinner was held at the Southern Hotel. The social meeting in the parlor began at 8 P.M., after which adjournment was had to the small dining-room. Those present sat down to dinner at 8.40. After justice had been done the repast, President Ockerson called the meeting to order, there being forty-three members and seven visitors present. He first announced the result of the election of officers for 1897 as follows: President, Edward Flad; Vice-President, William H. Bryan; Secretary, Richard McCulloch; Treasurer, Thomas B. McMath; Librarian, Julius Baier; Directors, J. A. Ockerson and B. H. Colby; Members Board of Managers of the Association of Engineering Societies, J. B. Johnson and E. A. Hermann.

The Secretary announced an application for membership from A. L. McRae, Consulting Electrical Engineer, endorsed by J. B. Johnson and E. J. Spencer, and G. S. Montgomery, Electrical Engineer with Laclede Power Company, endorsed by William H. Bryan and Abe Cook.

President Ockerson then addressed the Club on the work that it had accomplished during the past year, calling special attention to the excellent condition of its membership list and its finances. In closing, he introduced the new president, Mr. Edward Flad, who presided during the remainder of the evening. Mr. Flad spoke briefly, expressing his thanks for the honor conferred upon him, and pledging the Club his best efforts in advancing its welfare and asking the co-operation of every member in that direction.

President Ockerson then introduced the following resolution which was, on motion, unanimously adopted:

"*Resolved*, That the thanks of the Club be tendered Mr. William H. Bryan for the faithful and efficient manner in which he has discharged every duty devolving upon him as secretary during the past three years."

Mr. Bryan responded briefly, stating that such results as he had accomplished were due as much to the hearty co-operation of individual members as to his own efforts.

Mr. B. H. Colby then responded to the toast, "The Municipal Engineer," explaining the difficulties which beset the pathway of the engineer in city service.

Mr. E. J. Spencer spoke on the "Production and Distribution of Electricity," paying special attention to the advancements which have been made in this science during the past year.

Professor W. S. Chaplin discoursed upon "The Engineer in the Orient," dwelling upon the primitive condition of engineering in the far East, and the limited opportunities for engineers to find employment.

Mr. R. E. McMath addressed the Club on "Civil Service in Municipal Affairs," with special reference to the efforts now being made in this direction before the Charter Revision Commission. He called attention to the good and the weak points of the subject, and made a number of valuable suggestions.

After the completion of the regular programme, Mr. Abbott moved that a committee be appointed to attend the meetings of the Charter Revision Commission, with a view of urging the adoption of an amendment of the charter requiring the president of the Board of Public Improvements to be a civil engineer. After being seconded, the motion was discussed by Messrs. McMath, Pitzman and Holman. Mr. Ockerson moved that, in view of the lateness of the hour, the motion be laid on the table.

Seconded and carried. Adjourned.

William H. Bryan, *Secretary.*

Civil Engineers' Society of St. Paul.

St. Paul, Minn., December 7, 1896.—A regular meeting of the Civil Engineers' Society of St. Paul was held at 8.30 P.M.

Present, eleven members and six visitors. Mr. G. L. Wilson in the chair. Minutes of previous meeting read and approved.

A suggestion from the Secretary of the Association of Engineering Societies as to change of letter-head was acted upon favorably, to the extent that the words, "member of the Association of Engineering Societies,' be added to the present form. The thanks of the Society were voted Mr. C. F. Loweth for a photograph of the Redwing bridge, built after his plans and under his supervision. County Surveyors William Danforth, of Goodhue County, and C. A. Forbes, of Dakota County, asked the coöperation of the Society with the Minnesota Association of Surveyors and Engineers, the Minneapolis Engineers' Club, and the Engineering Department of the State University, in the endeavor to secure legislation in the matter of licensing measurers of land. Mr. G. L. Wilson, Mr. C. F. Loweth and Mr. J. H. Armstrong will serve as a committee in this affair.

Mr. Max Toltz then read a paper on "Paint Tests at the Great Northern Railway Laboratory." The result of the experiments pointed to graphite paints as best adapted for preservation of iron and steel structures. An hour's discussion followed the reading of the paper.

C. L. Annan, *Secretary.*

Montana Society of Civil Engineers.

December 12, 1896.—At the regular meeting of the Montana Society of Civil Engineers, Saturday evening, James S. Keerl, chairman of the Committee of Arrangements for the annual meeting, reported that the preparations were progressing favorably and that the meeting would probably be held in Great Falls. The programme now outlined will include a visit to the Great Falls of the Missouri and the smelters, and a trip to the Belt coal mines, with a banquet at the Park Hotel. It is intended to make the meeting one of the most interesting and in-

structive in the history of the Society, and it is hoped that every member in the State will attend.

The Committee on Nominations named for officers for the ensuing year: Charles W. Goodale, president; A. E. Cummings, first vice-president; M. S. Parker, second vice-president; A. S. Hovey, secretary and librarian; James S. Keerl, member of the Board of Managers of the Association of Engineering Societies; F. W. Blackford, trustee.

William A. Clarke, of Butte, and Frank Leonard, of Libby, were elected to membership in the Society.

The applications for membership of Frank Klepetko and C. W. Sweringer, of Great Falls; Donald Gillies, of Butte, and F. A. Heinze, of Trail, B. C., were read, and the Secretary was instructed to send out the usual letter ballots.

The members present at the meeting were: John Herron, A. E. Cummings, James S. Keerl, F. J. Taylor, Finlay McRae and F. J. Smith.

F. J. Smith, *Secretary*.

The Civil Engineers' Club of Cleveland.

Club Rooms, Case Library, December 10, 1896.—President Howe in the chair. Present, twenty-seven members and twenty visitors.

The minutes of the November meeting, after alterations as suggested by Mr. Searles, were approved.

Messrs. Culley and Osborn were appointed tellers to canvass the ballots for the admission to active membership of Mr. Walter C. Parmley.

The Secretary reported for the Executive Board the acceptance of the resignation of Mr. George E. Gifford, and the suspension, for non-payment of dues, of Mr. H. Grey.

The applications of Messrs. John B. Leeper, Valentine S. Ives, and Edmund M. Sawtelle for active membership, and of Messrs. Charles A. Otis and Edwin S. Mills for associate membership, were read.

It was suggested that the Secretary should hereafter keep a record of how many of those present were members and how many were visitors.

The Secretary offered a motion that hereafter the roll be called at each meeting. The motion was lost, and the Secretary left to find out as best he could. However, the Club passed a motion, introduced by Mr. Searles, that the Visitors' Book be kept open, and that the visitors be requested to sign the same at each meeting under the head of Miscellaneous Business.

Mr. Joseph W. Willard then read the paper of the evening entitled "Explosives: A brief history; their adaptation to the arts and engineering; possible future use in warfare of so-called high explosives."

At 10 P.M., Mr. Willard not having finished, it was agreed to postpone the reading of the remainder of Mr. Willard's paper and the discussion thereof until the next meeting of the Club, and, upon motion of Mr. Dodd, it was voted to have a semi-monthly meeting on the twenty second of this month.

Mr. Parmley was reported as unanimously elected.

The Club then adjourned. After the meeting, a light lunch was served.

F. A. Coburn, *Secretary*.

Case Library Building, Cleveland, Ohio, December 22, 1896. A semi-monthly meeting of the Club was held in the Club Rooms, Tuesday evening, President Howe in the chair. Present: Twenty-two members and eight visitors.

Mr. Joseph W. Willard presented a short and very interesting paper upon modern "Explosives," their manufacture and mode of use.

Dr. C. F. Mabery, of Case School of Applied Science, followed with a comprehensive demonstration of the chemistry of powder, and the various higti explosive compounds, and of their comparative properties and qualities.

After the meeting came the usual interesting visit and lunch.

F. A. Coburn, *Secretary.*

Technical Society of the Pacific Coast.

Regular Meeting, December 4, 1896.—Called to order at 8.30 p.m. by Past-President Grunsky.

The minutes of the last regular meeting were read and approved.

Mr. Edward F. Haas, Civil Engineer of Berkeley, California, was elected to membership by regular ballot.

The following letter was read:

London, E. C., November 18, 1896.

Mr. Otto von Geldern, *Secretary, Technical Society, San Francisco.*

Dear Sir:—Will you do me the favor to explain to the members of the Society that I very much regret not to have been able to reply at an earlier date to the very kind resolution of sympathy for me, passed by them last May? It was my hope and expectation to have gone to San Francisco last summer for a visit, when I hoped to have had the pleasure of seeing you and to have thanked them in person for their very much esteemed expressions of friendship and sympathy.

My plans at present are so indefinite, that I fear it may be some months before I can indulge myself the pleasure of a trip to America.

Please convey to the members of the Technical Society my cordial good wishes and sincere thanks, and believe me, Yours truly,

(Signed) John Hayes Hammond.

A Nominating Committee to select a ticket of officers for the ensuing year was elected by the members present; the five members of the Committee are: C. E. Grunsky, H. C. Behr, Adolph Lietz, Luther Wagoner, and C. I. Hall.

Mr. George W. Dickie read a paper, entitled "Industrial Education," which was discussed by members present.

The importance of the paper read by Mr. Dickie, created a desire to have the subject brought up again for discussion at the next regular meeting of the Society. The Secretary was instructed to prepare an abstract of the paper, and to circulate it to the members to start a more general discussion of the subject of "Industrial Education."

Meeting adjourned. Otto von Geldern, *Secretary.*

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